sensia

Rockwell Automation + Schlumberger

CALDON SVM 389Ci

Self-Verifying Ultrasonic Meter with G3 Transmitter

User Manual

MA23103, Rev. 01

IMPORTANT SAFETY INFORMATION

SYMBOLS AND TERMS

Read user instructions carefully and visually inspect the equipment to become familiar with the device before installing, operating, or maintaining it.

Equipment should be installed, operated, serviced, and maintained only by qualified personnel. Sensia assumes no responsibility for consequences arising from the use of this material.

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	DANGER A hazardous situation which, if not avoided, will result in serious injury or death.
	WARNING A hazardous situation which, if not avoided, can result in serious injury or death, major loss of property, or catastrophic business risk.
	WARNING – ELECTRICAL SHOCK An electrical hazard which will result in personal injury if instructions are not followed.
	CAUTION A hazardous situation which, if not avoided, can result in minor or moderate injury, loss of property, or business risk.
Important	Non-urgent information that may impact the outcome of a process or procedure.
Note	Additional information or a tip that may help the user to work more efficiently.
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REVISION HISTORY

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Section 1: Introduction

1.1 EQUIPMENT DESCRIPTION

The CALDON* SVM* * 389Ci* ultrasonic flowmeter is a highly sophisticated bidirectional flow measurement system that employs ultrasonic transit time to measure volumetric flow rate and evaluate the uncertainty in the measurement result. Its advanced signal and data processing are designed to provide robust, high accuracy measurement and unique self-verification capabilities.

CALDON SVM technology employs proven Caldon 8-path configuration for its primary measurements. The 8-path configuration uses pairs of crossed paths in each of four chordal planes to effectively cancel non-axial velocities and accurately integrate the axial velocity profile. The 8-path primary measurement is the foundation of our SVM 389Ci which has 16 paths in total and incorporates three significant features to produce an ultrasonic meter with unique and unrivalled self-verification ability:

- Primary (axial velocity) measurement verification per chord
- Fifth chordal measurement plane to facilitate 4-chord vs 5-chord estimation of flow profile uncertainty
- Vertical reflective path for detection of entrained gas or contamination.

SVM technology enables the simultaneous calculation of measurement uncertainty alongside each flow measurement calculation. In addition to the continuous and instantaneous output of uncertainty in terms of volumetric flow rate or a relative percentage value, SVM totalizes uncertainty values internally. The SVM 389Ci flowmeter contains an automatic fault detection system for verifying performance and alerting personnel when abnormal operating conditions are detected. For ease of troubleshooting, the SVM 389Ci flowmeter provides easy-to-interpret uncertainty and diagnostic information via Modbus communications and the local display.

This manual provides detailed instructions on the installation and operation of the flowmeter including the viewing of flow parameters and interpretation of diagnostic data viewed via the transmitter's display. Users who require a more detailed view of uncertainty, diagnostic and signal data can access the data via the CALDON USM Advisor software. The operation of this software is outside the scope of this manual. See the USM Advisor User Manual for details.

The SVM 389Ci flowmeter has two key components: a meter body and a transmitter.

Typically, the transmitter is mounted to the meter body, tested at the factory, and shipped as a fully assembled instrument, ready for installation.

1.1.1 SVM 389Ci METER BODY

The meter body contains 16 pairs of ultrasonic transducers and a temperature sensor (RTD). Refer to Figure 1.1, page 9 for a depiction of the meter body and transmitter assembly.

The meter body is a specially designed flow conduit that contains multiple pairs of transducer housings that are positioned to form ultrasonic paths at an angle to the flow direction. The transducers are installed inside these housings and are isolated from the fluid and external to the pressure containment. The four primary chordal planes are spaced in accordance with the Gaussian Method of flow integration.

Each transducer module contains a piezoelectric element that transmits and receives acoustic energy in the form of ultrasonic pulses.

* Mark of Sensia
* The SVM 389Ci is the latest addition to the Leading Edge Flow Meter (LEFM) family. It is designated SVM for Self-Verifying Meter. However, LEFM and SVM can be used interchangeably, e.g., the LEFM/SVM 389Ci is part of the LEFM 3xxCi family of meters.

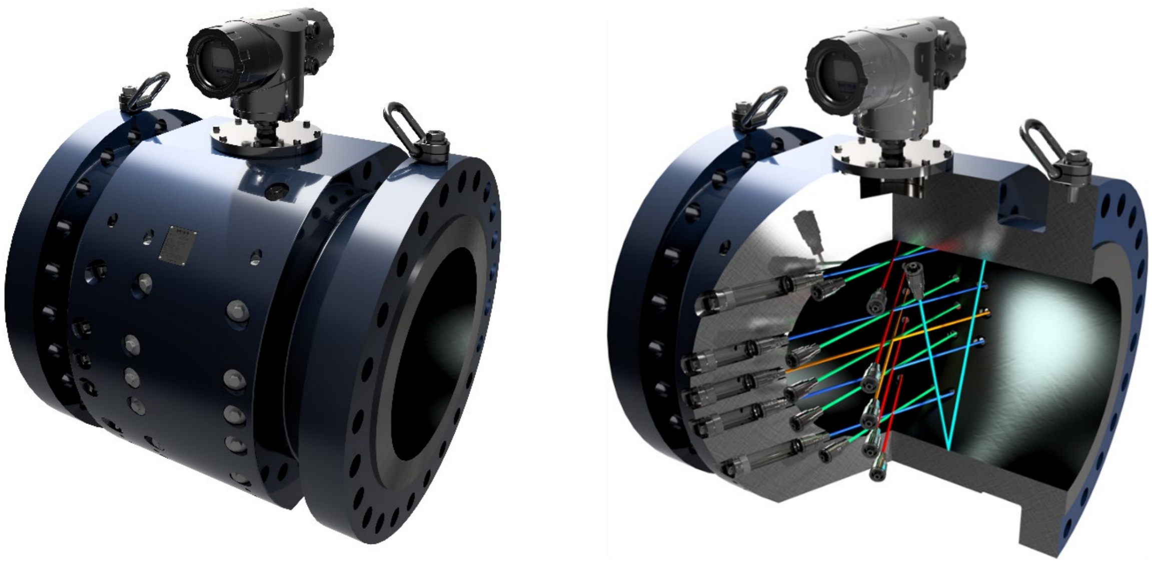


Figure 1.1—Example of meter body and transmitter assembly

1.1.2 G3 TRANSMITTER

The transmitter houses the display that provides readouts of flow data including flow rate, total flow volume, fluid properties, analog input data, alarm indication, fault detection, and diagnostic information.

The transmitter performs all control and timing for the generation and measurement of ultrasonic transit times. Signal and data processing is performed by specialized proprietary circuit boards that are designed to achieve high sampling rates, provide stable ultrasonic signals, and eliminate zero drift. The circuit boards within the transmitter are programmed to perform the following functions:

- Step through the ultrasonic path cycles
- Measure meter body temperature (for thermal expansion correction – see Section 4: Understanding Flow Calculations)
- Compute flow
- Communicate with external devices
- Generate pulse outputs and analog outputs

The transmitter offers the following inputs/outputs:

- Optional 4-20 mA analog inputs; choose from the following:
  - Product temperature
  - Product pressure
- Two optional 4-20 mA analog outputs; choose from the following:
  - Flow
  - Product temperature
  - Product pressure
- Communications
  - Up to three RS485 ports (half duplex) – Modbus RTU
  - Ethernet port (via copper or fiber) with Modbus TCPIP
  - Optional HART channel (operates on second analog output)
- Four digital outputs
  - Status outputs
  - Standard volume pulse outputs

The standard K-Factors used to configure transmitters at the factory are listed in Table 1.1. The user may optionally configure the K-Factor to meet individual needs. Refer to the meter display or Modbus register for the actual K-factor in use.

Table 1.1 Standard K-Factors

Size		K-Factor (P/CF)	K-Factor (P/m3)
Inches	DN		
12	300	28.3	1000
14	350	23.5	829
16	400	17.9	632
18	450	14.1	498
20	500	11.4	402
24	600	7.9	278
26	650	6.0	210
28	700	5.1	180
30	750	4.4	160
32	800	3.9	140
34	850	3.4	120
36	900	3.0	100

1.2 MODEL NUMBERS

1.2.1 METER BODY MODEL NUMBER

The meter body model number defines construction and features of the meter body. From the model number, a user can identify and verify the component type, meter size, piping thickness, construction material, flange rating/style, and enclosure type.

MODEL NUMBER CODE: SVM ABC-X-D-E-F-G-H-J-K-L-M-N-P-Q-R

Example: For a carbon steel 389Ci meter with Schedule 40, 150# raised-face flanges and G3 electronics mounted directly to the meter body, the model code is SVM 389Ci-G3-16-40-CF-150-A-W-L-A-N-A-1-L.

A =	3 FOR GAS METERS
B =	89 FOR 16 PATH SVM METERS
C =	Ci-G3 FOR INTEGRAL ELECTRONICS
D =	NOMINAL PIPE SIZE (e.g., 16 = 16 INCH ....)
E =	PIPE SCHEDULE (SCHEDULE 5 THRU 160 AND XXS)
F =	CF FOR FORGED CARBON STEEL CC FOR CAST CARBON STEEL SF FOR FORGED STAINLESS STEEL SC FOR CAST STAINLESS STEEL DF FOR FORGED DUPLEX STEEL DC FOR CAST DUPLEX STEEL LF FOR FORGED LOW TEMPERATURE CARBON STEEL LC FOR CAST LOW TEMPERATURE CARBON STEEL HF FOR HASTELLOY IF FOR INCONEL FORGED
G =	ASME FLANGE RATING (CLASS 150, 300, 600, 900, 1500, 2500)
H =	H FOR SINGLE TRANSDUCER ENCLOSURES INTEGRAL WITH METER BODY
J =	W FOR WELD NECK RAISED FACE FLANGES R FOR WELD NECK RTJ FACE FLANGES O FOR OTHER FLANGE VARIETY
K =	L FOR LOCTITE E40 EXP POTTING MATERIAL
L =	B FOR SECONDARY SEAL DESIGN TRANSDUCER HOUSING IN ACCORDANCE WITH ISA 12.27.01 (DUAL SEAL) C FOR DOUBLE O-RINGS
M =	N FOR NO PRESSURE PORT OPTION P FOR PRESSURE PORT OPTION
N =	A FOR ALUMINUM TRANSDUCER COVERS S FOR STAINLESS STEEL TRANSDUCER COVERS
P =	1 FOR ONE TRANSMITTER
Q =	G FOR GAS TRANSDUCER HOUSINGS
R =	"BLANK" FOR NO CUSTOM OPTION C FOR CUSTOM OPTION

1.2.2 TRANSMITTER MODEL NUMBER

The transmitter model number includes information that defines construction and features of the transmitter.

MODEL NUMBER CODE: G3MFFFCCPSEXYZ

MATERIAL

M =	A, ALUMINUM S, STAINLESS STEEL

FREQUENCY

FFF =	02S FOR 200KHZ BBS FOR A BROADBAND DESIGN

COMMUNICATIONS

CC =	HC FOR TWO RS-485 PORTS, ONE HART PORT, AND ONE COPPER ETHERNET SC FOR THREE RS-485 PORTS (ONE MASTER) AND ONE COPPER ETHERNET HF FOR TWO RS-485 PORTS, ONE HART PORT, AND ONE FIBER ETHERNET SF FOR THREE RS-485 PORTS (ONE MASTER) AND ONE FIBER ETHERNET

POWER OPTIONS

P =	D FOR DC POWER – 24 VOLTS A FOR AC POWER – 120/230 VAC

SUNSHIELD OPTIONS

S =	Y FOR WITH SUNSHIELD N FOR WITHOUT SUNSHIELD

ENTRY PORT

E =	1 FOR NPT PORTS 3/4 INCH NPT 2 FOR M25 ADAPTERS 3 FOR M20 ADAPTERS

APPROVALS

X =	0 FOR NO CLASS/DIV APPROVAL C FOR CLASS/DIV APPROVAL
Y =	0 FOR NO ATEX APPROVAL C FOR ATEX EXdb IIB + H_2 APPROVAL D FOR ATEX EXdb IIC APPROVAL
Z =	0 FOR NO IEC APPROVAL C FOR IECEX EXdb IIB + H_2 APPROVAL D FOR IECEX EXdb IIC APPROVAL

1.2.3 TRANSMITTER SPECIFICATIONS

Table 1.2 SVM 389 Transmitter Specifications

Material	
Standard	Aluminum (coated)
Corrosion Resistant	Stainless Steel
Size and Weight (if delivered separate from the meter body)	
Dimensions	14"x 8" x 6" = 152mm x 356 mm x 203 mm
Net Weight	15 lb (6.1 kg) Aluminum – Transmitter only
	Note – When attached to an aluminum junction box, the total could surpass 135 lb (61 kg), depending on the junction box brand
	40 lb (15.9 kg) Stainless Steel – Transmitter only
Power Requirements – DC Power	
Voltage	24 VDC (18 VDC to 30 VDC)
Current Draw	0.25 A at 24 VDC
Power Consumption	6 W
Power Requirements – AC Power	
Voltage	120 (60 Hz) / 230 (50 Hz) VAC
Voltage Range	108 VAC to 253 VAC
Frequency Range	47 Hz to 63 Hz
Rated Current Draw	0.06 A at 120 VAC / 0.03 A at 230 VAC
Nominal Power Consumption	7.3 W
Pulse Outputs/Alarm	
Pulse/Direction Outputs (4 Total)	0-5 V or 0-12 V
Alarm Status (4 Total)	5V or 12 V = normal operation
	0V = alarm condition
Communications	
RS485 (up to 3 total)	2 Wire – Modbus RTU
Ethernet	Copper (1 x RJ45 and TB2) or Fiber
HART	Optional
Analog Outputs (2 total)	
	4-20 mA (max load 650 Ohms)
Analog Inputs (3 total)	
	4-20 mA
	Meter body RTD is standard
Environment Requirements	
Storage Temperature	-58°F (-50°C) to 185°F (85°C)
Operating Temperature	-58°F (-50°C) to 158°F (70°C)
Altitude	Up to 5000 meters for DC applications, 2000 meters for AC applications (Contact Sensia for applications at higher elevations)

The intended use of this transmitter is a permanently connected installation, Equipment Class II, Pollution Degree 2, Continuous operation.

1.2.4 METER MARKINGS

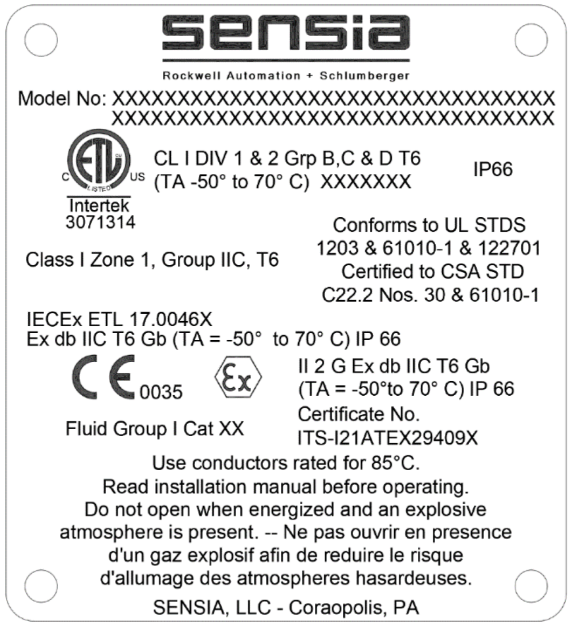


Figure 1.2— Meter body approvals nameplate example

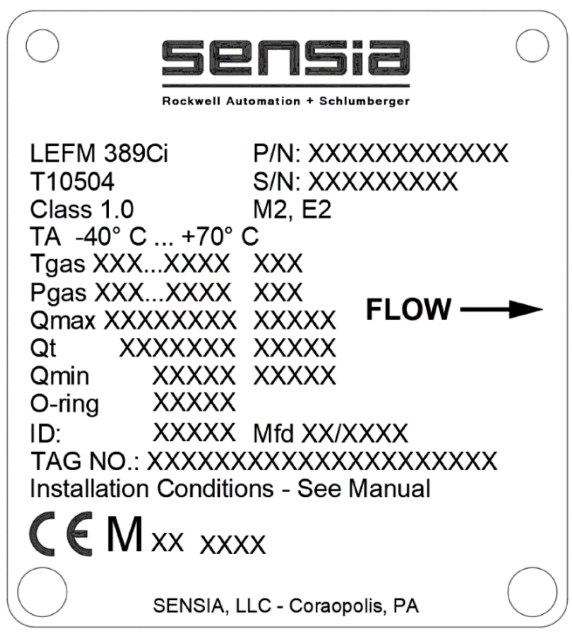


Figure 1.3—Meter body serial number nameplate example

Section 2: Meter Body Installation

SVM 389Ci flowmeters are designed for use with a broad range of process and environmental conditions. Durable construction permits conventional installation practices. The flowmeter body is typically fabricated of stainless steel, carbon steel, or duplex steel, depending on customer requirements. The flowmeter is designed to be as strong as or stronger than pipe and flanges of the same schedule, pressure class and material. For site stress analysis, the meter can be conservatively treated as equivalent pipe.

CAUTION

The weights of the flowmeter body are listed on the customer-specific General Arrangement Drawing. Never use the transmitter, conduit boxes or junction boxes for lifting or maneuvering the meter body. These components are not designed for the forces required to move the meter body and could be damaged.

CAUTION

If the equipment is likely to come into contact with aggressive substances, it is the responsibility of the user to take suitable precautions that prevent it from being adversely affected, thus ensuring that the type of protection is not compromised.

No external supports or special mounting pads are required or recommended for the SVM meter body. However, the piping immediately upstream and downstream of the flowmeter should be well supported in accordance with good piping practices and site seismic requirements.

2.1 LIFTING/HOISTING THE METER BODY

WARNING

If the swivel hoist rings have been used previously, inspect them for signs of wear, corrosion, or stress. If the rings appear damaged or corroded, DO NOT USE.

2.1.1 HOIST RING INSTALLATION

Use only Sensia swivel hoist rings (ordered separately; see Table 2.1) in the meter body end flanges.

DO NOT USE the following:

- Eyebolts
- Other hoist rings with the same screw size
- Heavy-duty hoist rings

Table 2.1 Hoist Ring Rated Weights and Part Numbers

Rated Weight (lbs)	Rated Weight (kg)	Thread	Sensia Part No.
1385	628	M8	9A-8504651
1980	898	M10	9A-8504652
2970	1347	M12	9A-8504653
4400	1996	M16	9A-8504655
7700	3493	M20	9A-8504657
9900	4491	M24	9A-8504659
14740	6686	M30	9A-8504661

1. Before installing hoist rings, refer to your company's hoisting and rigging standards. If no such company standards exist, refer to the Department of Energy (DOE) STD-1090-2011(Hoisting and Rigging Standard). Additional information can be found in OSHA 29 CFR 1926.251 (Rigging Equipment for Material Handling) and 1926.552 (Material Hoists, Personnel Hoists, and Elevators).
2. Identify the assembled weight of the meter body from the serial tag or by referencing the GA drawing.
3. Place the meter on a stable surface or platform capable of supporting its assembled weight.

WARNING
Failure to properly stabilize and support the meter body during installation or removal could allow the meter to shift or roll, posing a hazard that may result in equipment damage or serious injury, up to and including death.

4. Remove the plug bolts and sealing washers from the tapped holes on top of each meter body end flange and set them aside. The plug bolts will be replaced after the hoist ring is no longer required, as shown in Figure 2.1.

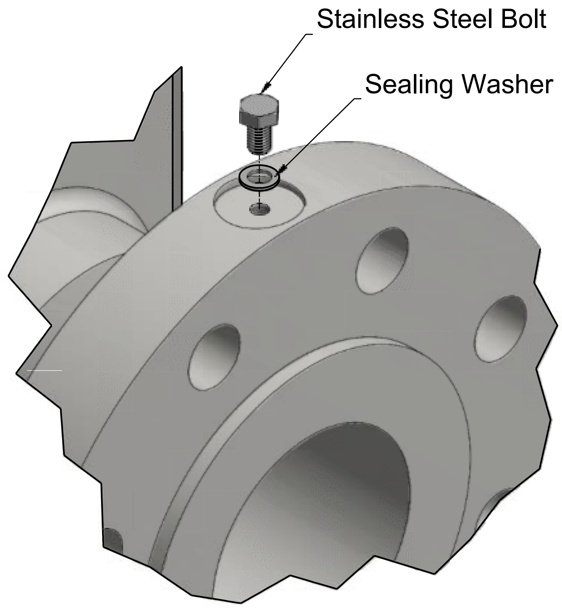


Figure 2.1—Stainless steel bolt and washer in tapped hole of meter body end flange

5. Screw the swivel hoist rings into the tapped holes. To ensure the hoist rings hold their rated load, the base of the hoist ring must be in full contact with the surface of the tapped holes before attempting to lift/hoist the meter body.
6. Torque the swivel hoist ring attachments to the site recommended limit for that bolt size. DO NOT over-torque.
7. Verify that the rings move freely in all directions.

2.1.2 SLING ATTACHMENT

WARNING
Ensure that the meter body is detached from all piping, pipe fittings, and/or meter tubes before lifting/hoisting the meter. Failure to take this precaution may result in damage to equipment and/or personal injury, up to and including death.

WARNING
Failure to properly stabilize and support the meter body during installation or removal could allow the meter to shift or roll, posing a hazard that may result in equipment damage or serious injury, up to and including death.

WARNING
NEVER attempt to thread one sling through both hoist rings. DO NOT exceed an angle of 90 degrees between the slings. Choose slings that exceed the swivel hoist ring load rating. Failure to follow these precautions may result in hoist ring failure, equipment damage, or serious personal injury, up to and including death.

1. Select two slings of equal length that exceed the load rating for the weight of the assembled meter body.
2. Visually inspect the slings for signs of wear, abrasion, or other damage. DO NOT USE if damage is detected.
3. Attach the slings to the hoist rings (see Figure 2.2).

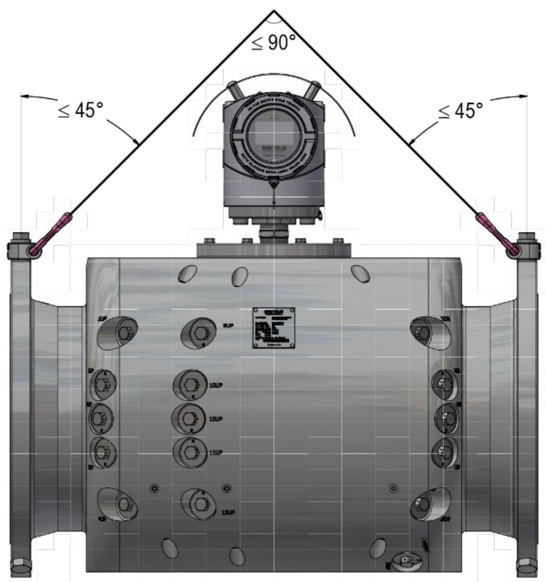


Figure 2.2—Proper sling attachment

Important Ensure that the angle between the slings is 90 degrees or less. DO NOT wrap slings around the meter body or the transmitter enclosure.

To avoid damaging the transmitter, ensure that the slings do not come into contact with the transmitter enclosure. Consider using a spreader bar (as shown in Figure 2.3) to ensure that the angle relative to the vertical does not exceed 90 degrees.

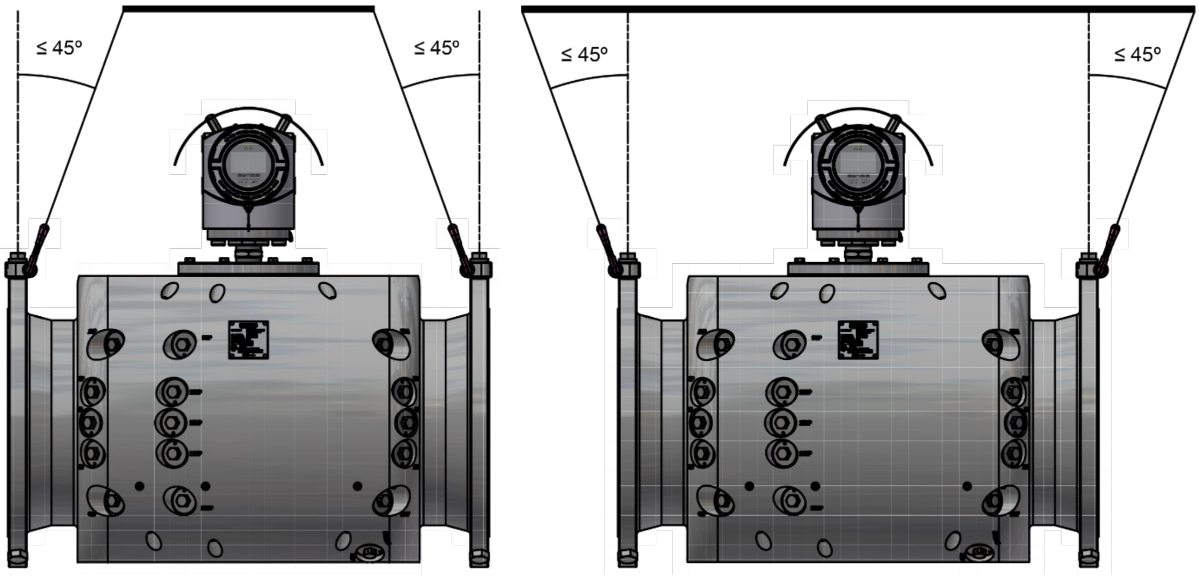


Figure 2.3—Hoist rings with a lifting bar above the electronics unit allow for uniform lifting.

CAUTION

To avoid damaging the swivel hoist rings, never use cables, hooks, or chains to lift the meter body. Lift the meter gradually. Exposing the swivel hoist rings to shock loads can result in damage to the hoist ring. DO NOT USE any swivel hoist ring exposed to shock loads.

4. After lifting, remove the swivel hoist rings and store away from exposure to moisture, extreme temperatures, and other adverse conditions.
5. Reinsert the plug bolts into the tapped holes to protect them from debris and corrosion.

2.2 METER INSTALLATION

Install the flowmeter so that:

- The primary measurement chords are horizontal (with the transmitter on top) to decrease the likelihood of debris accumulating in the sensor wells.
- The meter is not located at a low point in the system which could allow liquid accumulation.
- The flow arrow should be pointing in the direction of “positive” flow.
- All wiring to the transmitter is routed in shielded conduit/armoured cable that meets site environment specifications.
- All power connections from site shall go through a properly rated equipment switch or circuit breaker employed as a disconnecting device (see Table 1.2, page 13, for ratings). This switch shall be easily accessed and be marked as the disconnecting switch for the transmitter. This switch shall meet the requirements of IEC 60947-1 and IEC 60947-3 and site electrical codes.
- If using DC power, power cable must be installed in separate conduit from all other cabling. This is to meet the requirements of IEC 61000-4-4 (2004-07).
- To limit uncertainty caused by pipe fittings and fluid dynamic effects, install the SVM 389Ci model per the following guidelines.
  - The adjoining straight pipe should be of the same schedule as the meter.
  - The SVM 389Ci does not normally require the use of a flow conditioning element. An uninterrupted upstream pipe 5 diameters in length is adequate in most applications. In situations where there is a constriction upstream of the meter that is smaller than the diameter of the meter run piping (such as a reduced bore valve or strainer), it is recommended that this be separated from the meter by a pipe at least 15 pipe diameters in length.

- Downstream of the meter there should be a straight length of pipe at least 3 pipe diameters prior to any bends, tees, reducers, expanders or valves etc.
- In uni-directional applications, temperature elements and pressure connections should be located downstream of the meter.
- Intrusive temperature elements should be at a distance of at least 2 pipe diameters from the meter. Non-intrusive pressure connections may be located within 2 diameters of the meter.

Refer to Figure 2.4 for details. For application-specific recommendations or more detailed installation guidance, contact Sensia.

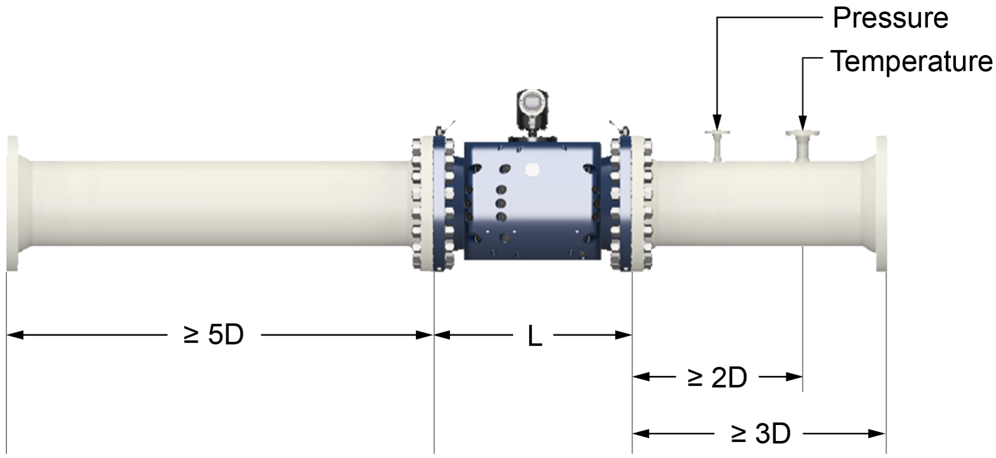


Figure 2.4—SVM 389Ci installation recommendations

Section 3: Transmitter Connections

CAUTION
The physical properties, configuration settings, and calibration of the meter body are pre-programmed into the transmitter; therefore, the meter body and transmitter are manufactured as a matched set and must be installed as a pair. Failure to install transmitters and meter bodies as matched sets can result in erroneous flow measurements.

3.1 TRANSMITTER INSTALLATION PROCEDURE

Important All equipment should be installed by a licensed electrician in accordance with NEC/CEC or local codes. At a minimum, install a disconnect switch in series with the transmitter power input.

All wiring to and from the transmitter must be routed through grounded/shielded metal conduit or equivalent that meets site environment specifications.

All power connections from site shall go through a properly rated equipment switch or circuit breaker employed as a disconnecting device (see Table 1.2, page 13, for ratings). This switch shall be easily accessed for disconnecting and be marked as the disconnecting switch for the transmitter. This switch shall meet the requirements of IEC 60947-1 and IEC 60947-3 and site electrical codes.

For Class I, Div 1 installations, conductor insulation for external circuits must be rated for 300V and a minimum temperature of 85ºC.

3.1.1 TRANSMITTER LOCATION

To ensure that the proper supply voltage reaches the transmitter, the distance between the transmitter and its power source must not exceed the maximum distance indicated below (based on the wire gage used):

Table 3.1 Distance Required from Power Source

Wire Gage	Max Distance (m)	Max Distance (ft)
12	1082.2	3550.4
14	679.7	2229.8
16	429.0	1407.3
18	269.1	882.9
20	169.1	554.6
22	106.3	348.6
24	66.9	219.6

3.1.2 TRANSMITTER TERMINATIONS

WARNING
Before inspecting components, open the power supply circuit breaker. Failure to do so can result in electrical shock and/or explosion.

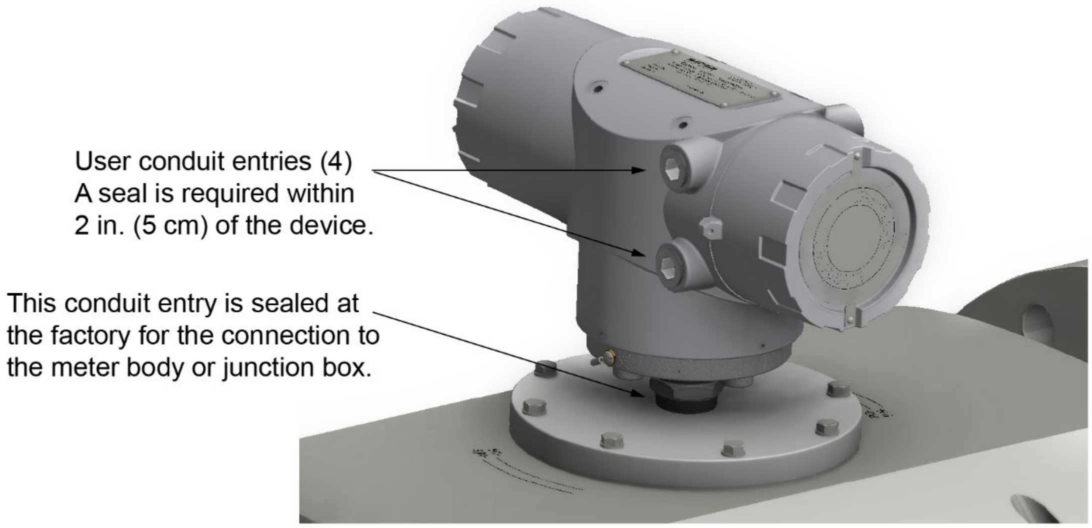


Figure 3.1—Fully assembled transmitter

The four conduit entries at the rear of the transmitter are for user connections. A hazardous area conduit seal is required within 2 inches (5 cm) of the device on every entry used. Unused entries must have plugs installed to be wrench tight with at least five threads fully engaged for a ¾ inch NPT connection or eight threads fully engaged for an M25 connection.

> **WARNING**
> If ATEX approved glands are to be used, they shall be types that include compound filled seals around individual cores. (Refer to EN 60079-14 clause 10.4.2).

The wires should then be routed so that the terminations can be made at the terminal blocks under the rear cover. Refer to Figure 3.2 for the location of the transmitter terminations on the IOP terminal blocks and identification of the pin numbers. The inside of the rear cover has a diagram of the user connections.

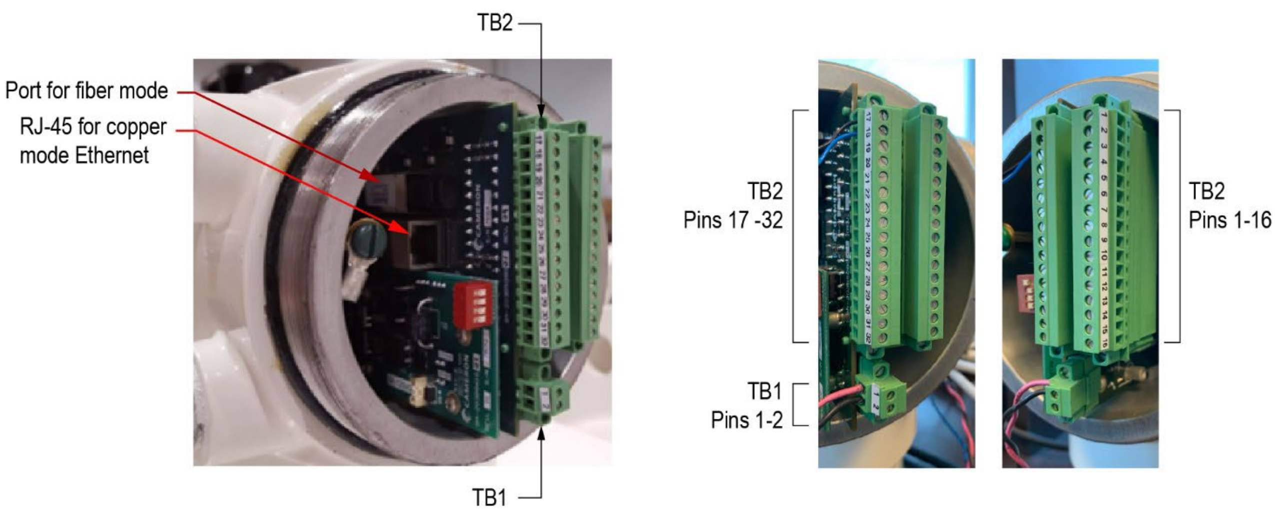


Figure 3.2—User terminations, rear view

3.2 WIRING INSTRUCTIONS

3.2.1 POWER TERMINATIONS (TERMINAL BLOCK 1)

TB1 contains the power terminations, described below in Table 3.2. The schematics for the power terminations are shown in Figure 3.3 and Figure 3.4, and earth ground terminations are shown in Figure 3.5.

Table 3.2 Power Terminations – Recommended 16 to 20 AWG wire†

DC Power	
TB1, Pin 1	+24 VDC
TB1, Pin 2	(RETURN)
AC Power	
TB1, Pin 1	+120/230 VAC LINE
TB1, Pin 2	NEUTRAL

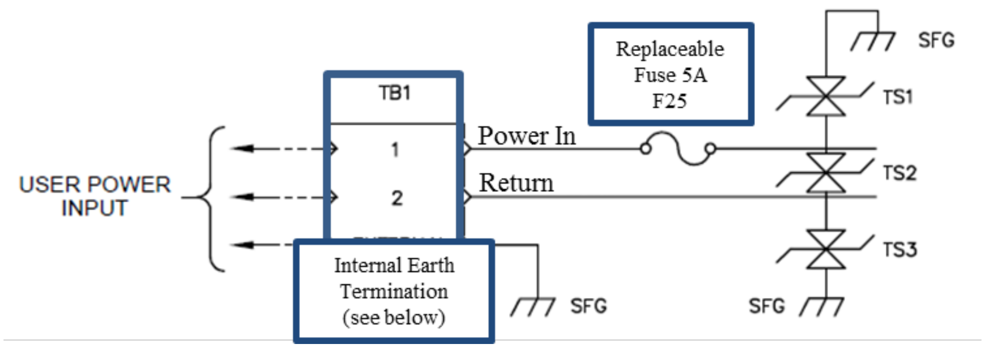


Figure 3.3—DC power terminations

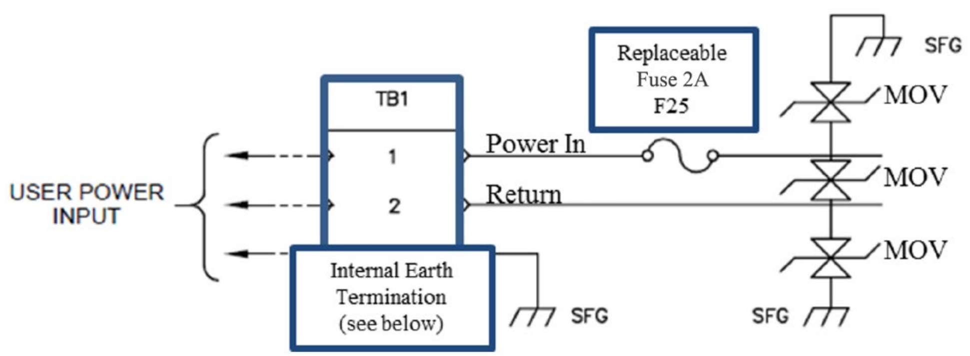


Figure 3.4—AC power terminations

† 14 AWG is allowable.

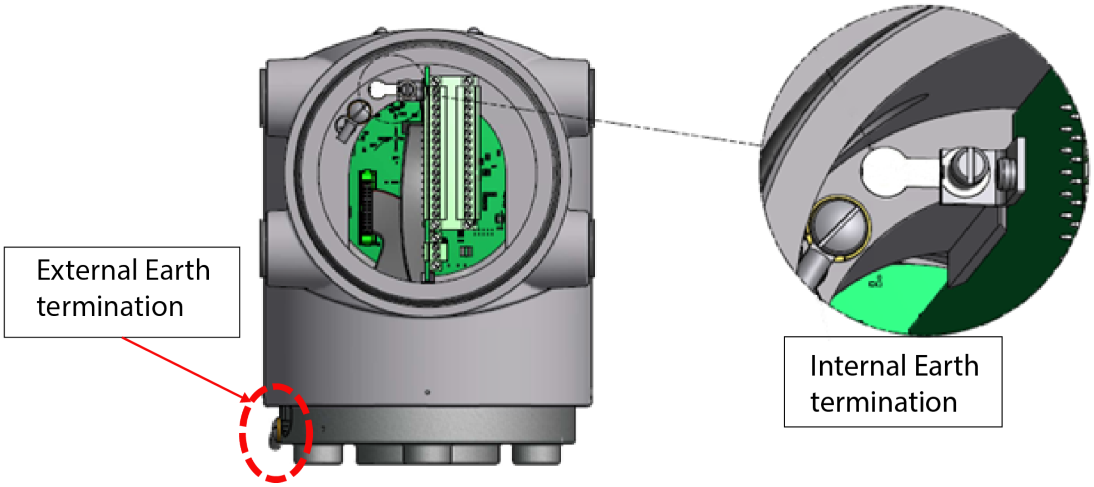


Figure 3.5—Power terminations
(TB1 has terminals 1 and 2 only; safety earth/ground shown in two places)

3.2.2 USER 1 AND USER 2 INPUTS/OUTPUTS

There are two groups of inputs/outputs in this transmitter. The groups are organized as User 1 and User 2. Each user group is galvanically isolated from the other user group and from the incoming power supply. Inputs/outputs within a user group have a common isolated ground. Accordingly, all inputs/outputs will be listed according to the user group.

3.2.3 ANALOG INPUTS (TERMINAL BLOCK 2)

TB2 contains the transmitter's analog inputs, described below in Table 3.3. A typical schematic for the analog inputs, including a depiction of the terminal block 2 configurations, is shown below in Figure 3.6.

Table 3.3 Analog Inputs (User 1) – Recommend 16 to 28 AWG wire

Analog Input 1	TB2, Pin 3	4 to 20 mA (+)
	TB2, Pin 4	4 to 20 mA (-)
Analog Input 2	TB2, Pin 5	4 to 20 mA (+)
	TB2, Pin 6	4 to 20 mA (-)
Analog Input 3	TB2, Pin 7	4 to 20 mA (+)
	TB2, Pin 8	4 to 20 mA (-)

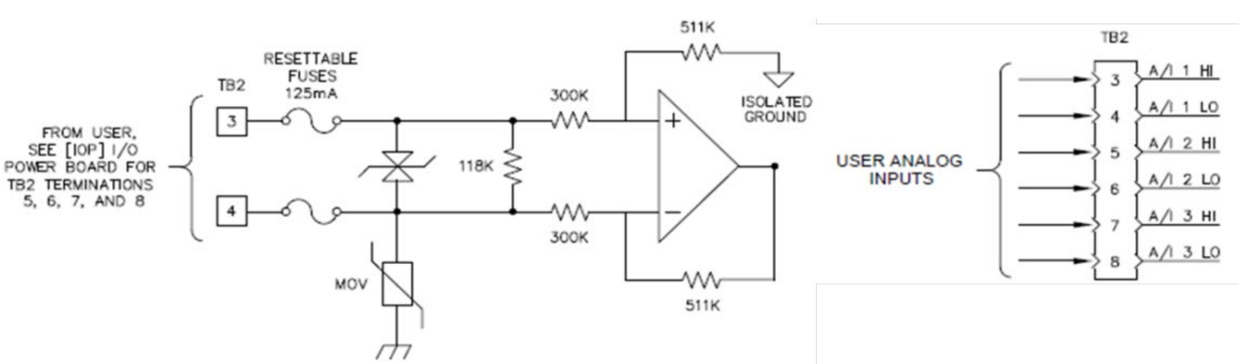


Figure 3.6— Typical analog input

3.2.4 ANALOG OUTPUTS (TERMINAL BLOCK 2)

TB2 contains the transmitter's analog outputs, described below in Table 3.4. A typical schematic for the analog outputs, including a depiction of the terminal block 2 configuration, is shown below in Figure 3.7.

Table 3.4 Analog Outputs (User 2) – Recommended 16 to 28 AWG wire

Analog Output 1	TB2, Pin 9	4 to 20 mA (+)
	TB2, Pin 10	4 to 20 mA (-)
	TB2, Pin 11	Ground
Analog Output 2	TB2, Pin 25	4 to 20 mA (+)
	TB2, Pin 26	4 to 20 mA (-)
	TB2, Pin 27	Ground

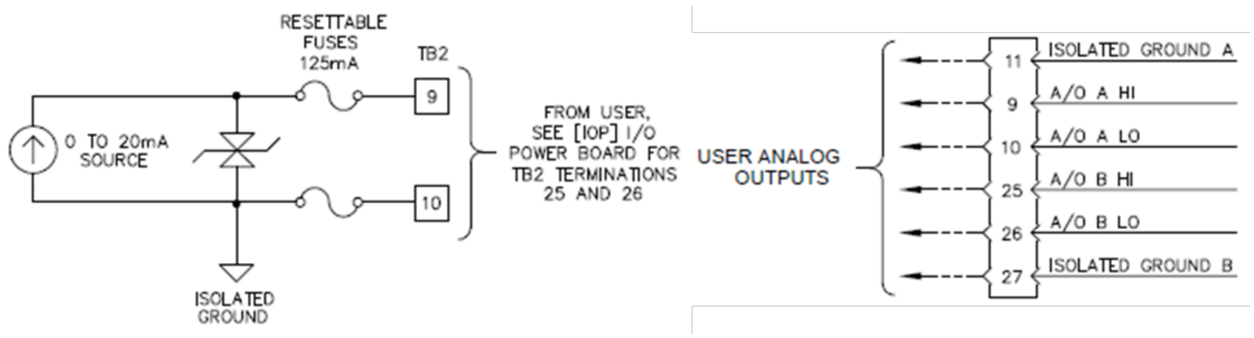


Figure 3.7—Typical analog output

3.2.5 OPTIONAL HART (TERMINAL BLOCK 2)

TB2 contains the transmitter's analog outputs, described below in Table 3.5. Connections are made to the Analog Output 2 terminals. HART does not interfere with the analog function.

Table 3.5 Optional HART Output – Recommended 16 to 28 AWG wire

HART	TB2, Pin 25	4 to 20 mA (+)
	TB2, Pin 26	4 to 20 mA (-)
	TB2, Pin 27	Ground

3.2.6 DIGITAL OUTPUTS (TERMINAL BLOCK 2)

TB2 contains the transmitter's digital outputs, described below in Table 3.6, page 25. The voltages, +V, for the digital signals are active, selectable as either 5 volts or 12 volts, and electrically isolated. The output impedance is 249 ohms. These outputs are intended for high-impedance (1 MΩ) devices.

Pulse B can be configured to indicate volume or flow direction. The desired function is selected by a Modbus register. Refer to either the Modbus manual IB1504 or the USM Advisor manual for changing parameters.

Table 3.6 Digital Signals – Recommended 16 to 28 AWG wire

Signal	Pulse Description	Voltage Description	Terminal			
			User 1		User 2	
Pulse A (Volume)	Pulse A precedes Pulse B by 90 degrees = forward flow	—	TB2	Pin 12 (+)	TB2	Pin 28 (+)
	Pulse B precedes Pulse A by 90 degrees = reverse flow			Pin 16 (-)		Pin 32 (-)
Pulse B (Volume)/ Direction	Pulse B precedes Pulse A by 90 degrees = reverse flow	0V = forward flow	TB2	Pin 13 (+)	TB2	Pin 29 (+)
	Pulse A precedes Pulse B by 90 degrees = forward flow	+V = reverse flow		Pin 16 (-)		Pin 32 (-)
Status A	—	0V: alarm condition	TB2	Pin 14 (+)	TB2	Pin 30 (+)
		+V: normal operation		Pin 16 (-)		Pin 32 (-)
Status B	—	0V: alarm condition	TB2	Pin 15 (+)	TB2	Pin 31 (+)
		+V: normal operation		Pin 16 (-)		Pin 32 (-)

Note: Pulse A may be configured to positive flow only with Pulse B assigned to negative flow.

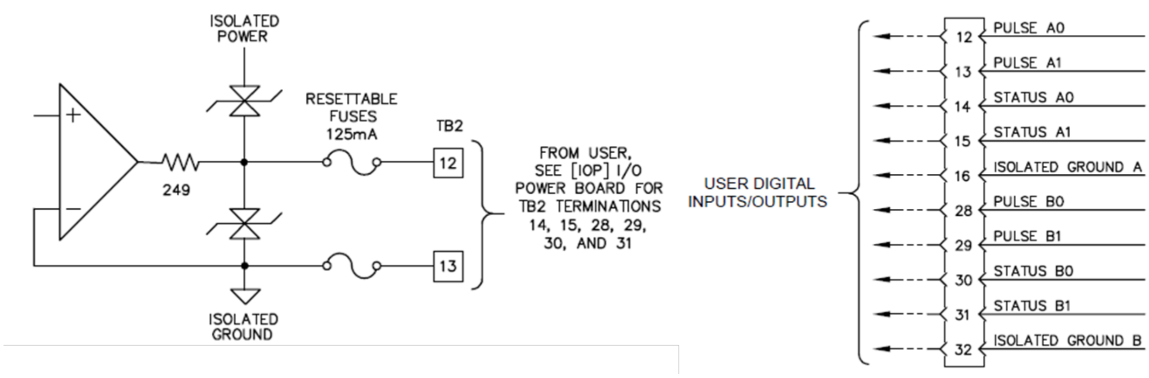
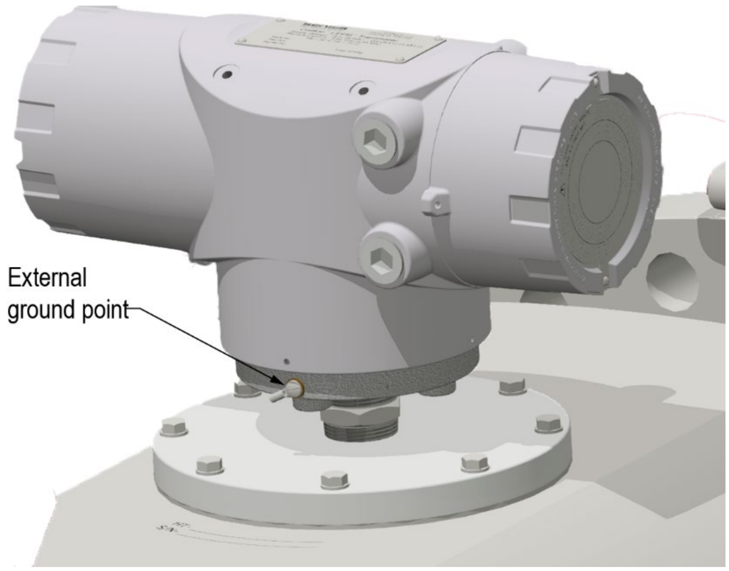


Figure 3.8—Typical digital signals

3.2.7 GROUNDING

There are earth points on the outside of the transmitter enclosure. There are grounding points on the inside and outside of the transmitter enclosure. Refer to Figure 3.9, page 26, for the location of the earth point. For ATEX applications, both earth points should be used. Follow all other site guidelines regarding grounding/earthing.



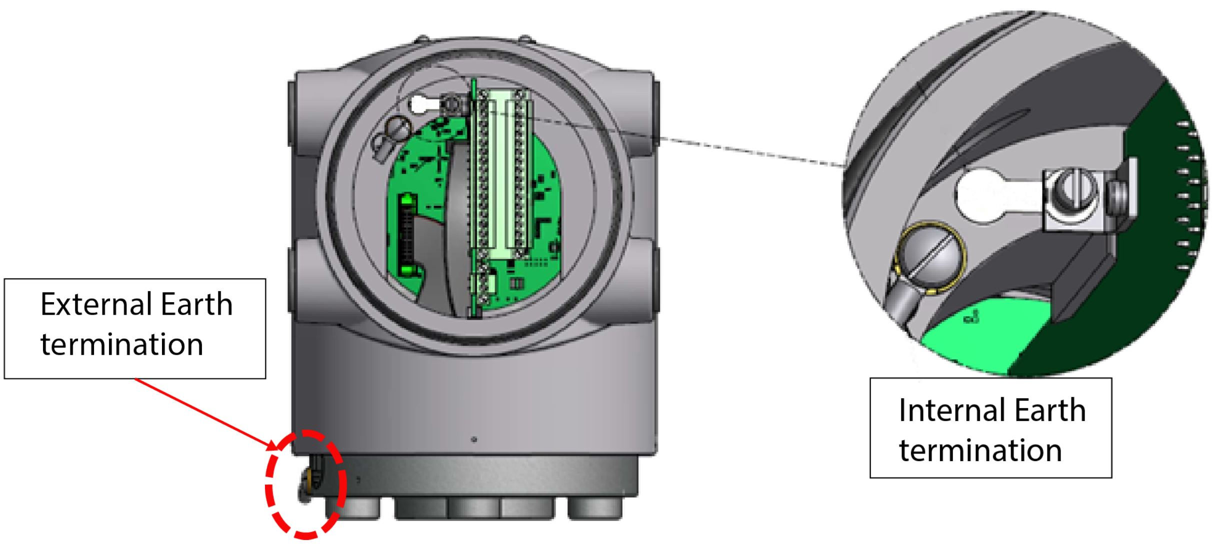


Figure 3.9—Earth points on transmitter body
(refer to Table 3.7 for isolated ground connections to be made by user)

Table 3.7 Ground Connections
Recommended 18 AWG wire (internal) and 16 AWG wire (external)

Terminal (9A-203B508)	Terminal (9A-204B169)	Description
TB2, Pin 11	TB2, Pin 11	Isolated ground for User 1
TB2, Pin 16	TB2, Pin 16	Isolated ground for User 1
TB2, Pin 21	N/C	Isolated ground for User 2
TB2, Pin 22	N/C	Isolated ground for User 2
TB2, Pin 27	TB2, Pin 27	Isolated ground for User 2
TB2, Pin 32	TB2, Pin 32	Isolated ground for User 2
TB2, Pin 23	N/C	Chassis ground
TB2, Pin 24	N/C	Chassis ground

Note Do not connect the isolated grounds to the earth ground; this defeats the isolation the electronics provide. Generally, User 1 and User 2 grounds are not connected to each other. These grounds are intended for separate users. These isolated grounds should be connected as appropriate to the ground where the signals are going.

3.2.8 REMOTE DATA COMMUNICATIONS

The legacy 9A-203B508 IOP supports remote Ethernet data communications via an RJ45 connector or an MTRJ fiber connector. The newer 204B169 IOP supports three Ethernet communication ports: an RJ45 connector, an MTRJ fiber modem, and an additional copper connection on the terminal block. See Table 3.8 for the connections. With the 9A-204B169 IOP, all networking options can be concurrent.

Note Concurrent ethernet connections are only available when IOP part number 9A-204B169 is being used. When IOP part number 9A-203B508 is in use the CTC must be configured to match the version of IOP in use and only one connection type is enabled via the use of solder bridge connections on the boards.

Table 3.8 Ethernet Connections (IOP Comparison)

	Concurrent Connections	RJ45 Copper	MTRJ Fiber	Copper (Terminal)
Current IOP 9A-204B169	Yes	X	X	X
Legacy IOP 9A-203B508 G01,G03,G05,G07	No	X		
Legacy IOP 9A-203B508 G02,G04,G06,G08	No		X	

Table 3.9 9A-204B169 – TB Copper Connections

Wired Ethernet Terminal Block	TB2, Pin 21	TX -
	TB2, Pin 22	TX +
	TB2, Pin 23	RX -
	TB2, Pin 24	RX +

Figure 3.10, page 28, shows the locations of the RJ45 (copper) and the MT-RJ (fiber) connections on the IOP board.

Note The Ethernet connection is electrically isolated from both user groups (e.g., independently isolated).

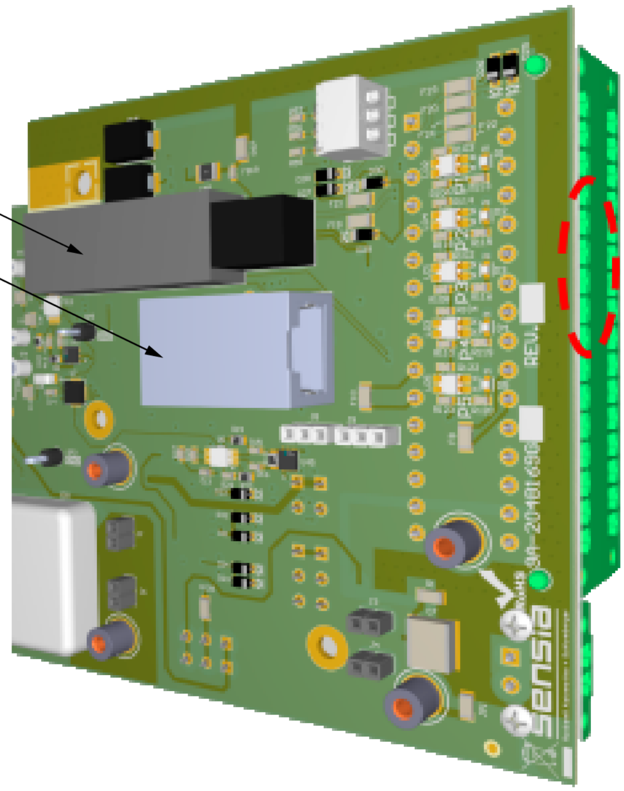


Figure 3.10—Ethernet locations

3.2.9 SERIAL COMMUNICATIONS

The serial communications are half-duplex (two-wire). Terminations for serial communications are provided in Table 3.10. A typical schematic showing the serial communications is shown below in Figure 3.11, page 29.

Table 3.10 Terminations for Serial Communications – Recommended 16 to 28 AWG wire

Port Name	Termination		User
COM1	TB2, Pin 1	Transmit/Receive (-)	1
	TB2, Pin 2	Transmit/Receive (+)	1
COM2	TB2, Pin 17	Transmit/Receive (-)	2
	TB2, Pin 18	Transmit/Receive (+)	2
COM3 (Not available with optional HART)	TB2, Pin 19	Transmit/Receive (-)	1
	TB2, Pin 20	Transmit/Receive (+)	1

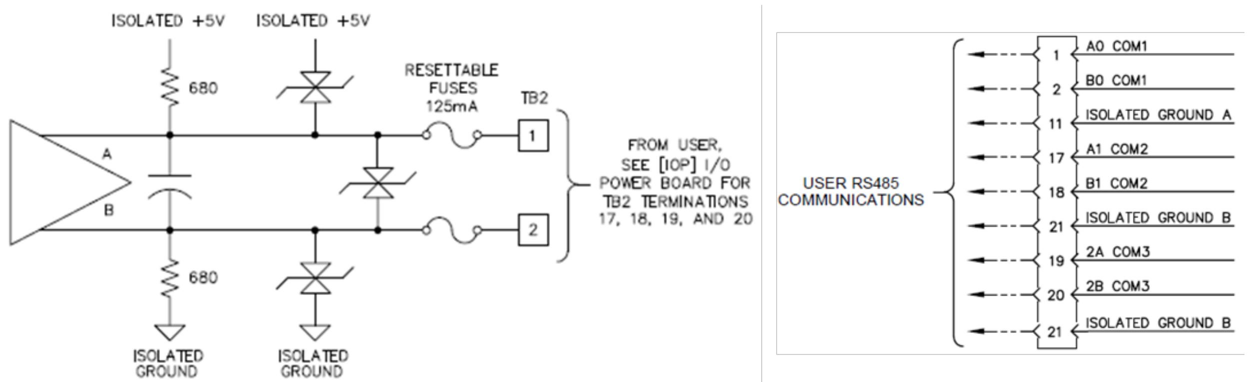


Figure 3.11—Typical RS485 communications

3.3 METER INSTALLATION CHECK-OUT

WARNING
Never open the transmitter when it is energized. Before inspecting components, open the power supply circuit breaker. Failure to do so can result in electrical shock or an explosion.

To validate a meter's installation, perform the following procedure. For troubleshooting information, see Section 7: Troubleshooting and Diagnostics.

1. Verify the meter is oriented with the transmitter on top of the meter body and the adjoining pipe work is in accordance with installation recommendations.
2. Verify the upstream pipe diameter is concentric with the meter body.
3. Verify all field terminations have proper continuity and isolation from each other and earth. Verify connections are good with respect to insulation.
4. Verify electronics turn on. The two LEDs on the display should be lit and the display is working.
5. Verify Modbus communications are operational. (Use USM Advisor software to test Modbus communications on the RS-485 connection or the Ethernet connection.)
6. Verify meter operation according to Section 5, Operations.
7. Use USM Advisor software to force outputs (current and pulses). Verify forced outputs are within 0.1% on current and within 0.01% on pulse frequency. For more information on forced outputs, see Output Test Mode below or consult the USM Advisor manual.

Note — Always return the meter to normal operation following the use of forced outputs in Output Test mode.

8. If the pipe is pressurized, contact Sensia Technical Support for detailed commissioning steps.

3.3.1 OUTPUT TEST MODE

The Output Test mode is used during field testing or verification checks. This output test is best done using the Sensia provided software, USM Advisor.

Section 4: Understanding Flow Calculations

4.1 MEASURING FLOW VELOCITIES

SVM ultrasonic flowmeters use pairs of transducers to send ultrasonic pulses to one another along measurement paths. The velocity measurement paths are at an angle to the fluid flow. The ultrasonic transit time along a path depends upon the direction of travel and both the speed of sound (SOS) in the fluid and the velocity of the fluid along the path. The transit time is shorter for pulses that travel downstream with the flow than for pulses that travel upstream against the flow.

$$t_{up} = \frac{L}{c - v_{axial}cos\theta - v_{transverse}sin\theta}$$

$$t_{down} = \frac{L}{c + v_{axial}cos\theta + v_{transverse}sin\theta}$$

where

t_{up}	= upstream transit time
t_{down}	= downstream transit time
L	= path length
c	= speed of sound in fluid
v_{axial}	= flow velocity in the direction of the pipe axis
$v_{transverse}$	= transverse (non-axial) flow velocity

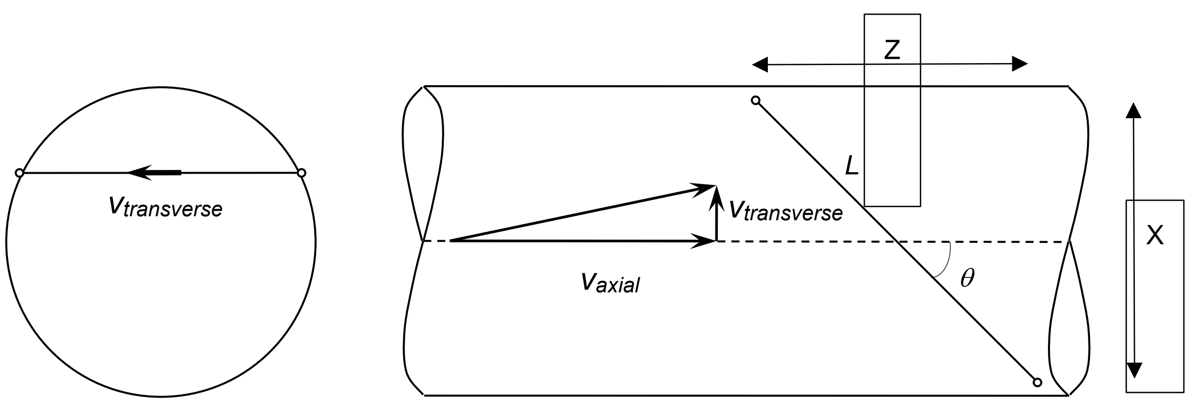


Figure 4.1—Illustration of the transit time principle

When transit times are measured in both directions, the above equations can be solved to obtain a path velocity result:

$$v_{path} = \frac{L(t_{up} - t_{down})}{2cos\theta t_{up}t_{down}} = v_{axial} + v_{transverse}tan\theta = v_{axial} + \frac{X}{Z}v_{transverse}$$

where X and Z are the projections of the path in the transverse and axial directions, respectively.

Using this method, the path velocity measurement v_{path} is independent of the velocity of sound. Consequently, variations in temperature, composition, etc. have no direct influence on the velocity results.

The equation above shows that the velocity measured on a single path is sensitive to both the wanted (axial) component of flow velocity and unwanted or interfering effect of non-axial velocity.

The Caldon SVM uses multiple paths in each chordal plane. These paths are designated as A, B and C as illustrated in Figure 4.2.

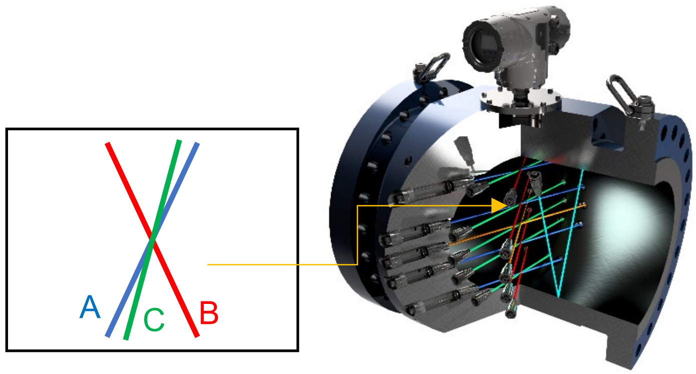


Figure 4.2—Three paths per chordal plane as used in the Caldon SVM

Any two paths can be combined to eliminate the transverse velocity and solve for the axial velocity. For example, using the path velocities from paths A and B, the axial velocity can be obtained as follows:

$$v_{axialAB} = \frac{\left(v_B - v_A \frac{Z_A X_B}{X_A Z_B}\right)}{\left(1 - \frac{Z_A X_B}{X_A Z_B}\right)}$$

This result shows that the influence of non-axial flow can be cancelled out of the equations by combining pairs of paths. Therefore, flow conditioning for removal of non-axial flow/swirl is not necessary in SVM flow meters. For the primary velocity measurement, paths A and B are used, which have equal but opposite angles to the pipe axis, such that $Z_B = Z_A$ and $X_A = -X_B$ and hence:

$$v_{axialAB} = \frac{v_B + v_A}{2}$$

4.2 MEASURING FLOW RATE

The primary flow measurement in the SVM flowmeter is performed using paths A and B in the four primary chordal planes. These paths are designated as 1 to 8 and arranged in crossed pairs in each of the four primary chordal planes as illustrated in Figure 4.3, page 32. Crossed pairs are used to cancel non-axial flow when solving for the flow velocity as described above. The four chord heights are arranged according to the rules of Gaussian quadrature and enable accurate averaging of the flow velocity profile (Figure 4.2).

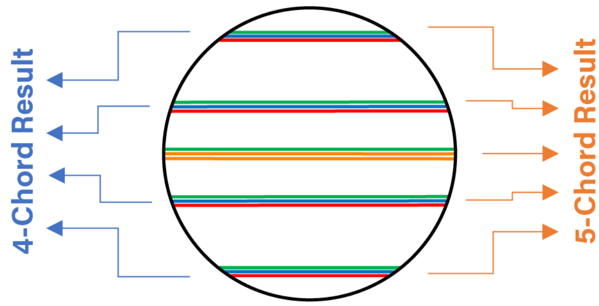


Figure 4.3—Chordal planes used for the primary velocity (4-chord) and velocity profile verification (5-chord)

Paths on the diametric plane are used to calculate a fifth value of axial velocity that is used in combination with the four primary chordal velocity results to compute a 5-chord result for velocity profile verification and uncertainty analysis.

During manufacturing, precision measurements of inside diameter (ID), path lengths and path angles are recorded and input to a configuration file for use in calculating the volumetric flow rate, supplemented by appropriately determined calibration inputs.

4.2.1 TEMPERATURE COMPENSATION

SVM 389 flowmeters can automatically compensate for pipe thermal expansion and contraction using an integrated meter body temperature measurement. This measurement can be used to apply the correction for thermal expansion in the meter's electronics according to ISO17089. This compensation can be disabled if a user prefers to perform the compensation in an external flow computer. However, compensation using the meter's own measurement of temperature has the advantage that it can be active during calibration and use and reflects the actual meter body temperature.

Compensation using an external measurement of the liquid temperature could introduce uncertainty as the temperature may differ from the body temperature and requires the calibration temperature to be known. Use of an external temperature measurement can facilitate periodic calibration of the temperature element, which cannot easily be done for the internal temperature measurement.

Care should be taken to ensure that the compensation is performed only once, either in the meter electronics or the flow computer.

Section 5: Operations

5.1 DEFINITIONS

Chord – Chordal plane in which a path is located, numbered 1 through 5

- Chords 1 to 4 are numbered top to bottom, excluding the diameter.
- Chord 5 is the diameter.

Plane – Vertical plane in which a path is located, designated with letters A, B and C

- Paths in planes A and B are primary measurement paths.
- Paths in plane C are used for verification purposes and input to uncertainty calculations.

Path – each pair of transducers makes a path which is located in accordance with the above. Path numbering is shown in Figure 5.1. For example, Path 1 is located in Chord 1 and vertical Plane A.

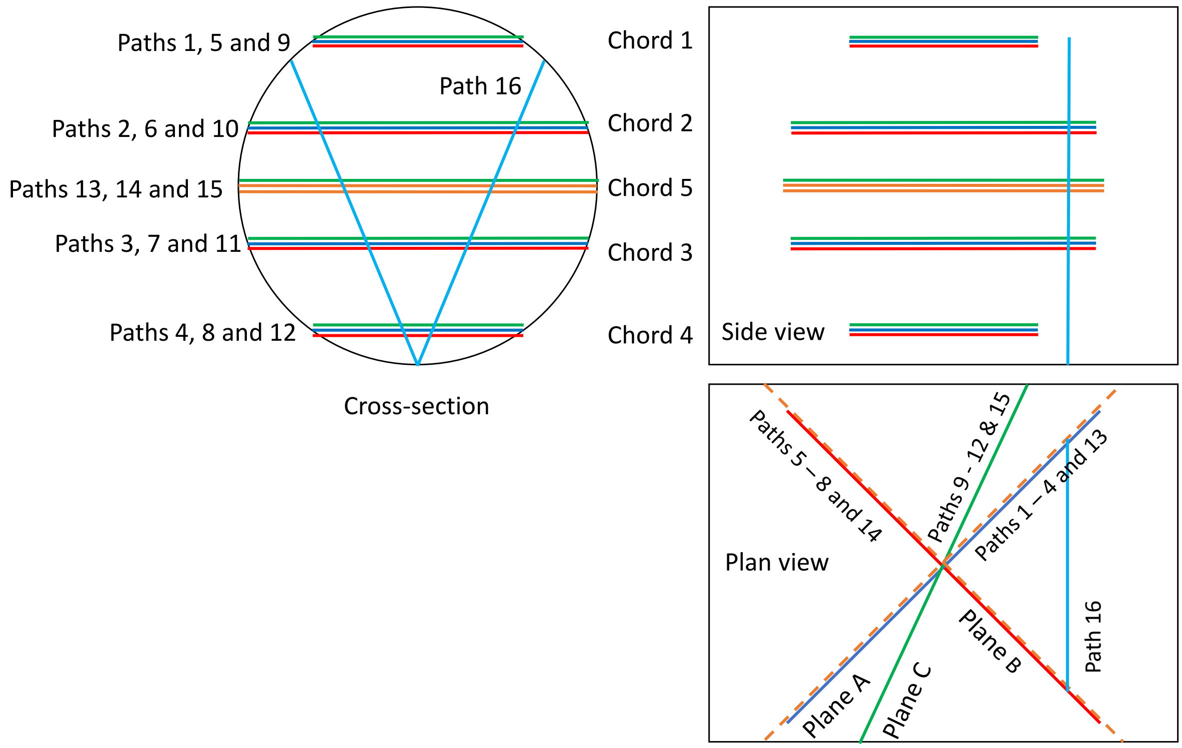


Figure 5.1—Illustration of chord, plane, and path

SNR – Signal to Noise Ratio

Gain – Required gain to amplify signal

% Performance – Percentage of data accepted by the processor

SOS – Speed of Sound

IOP – Input Output and Power Board

CTC – Control and Timing Card

MXR – Multiplexer, Transmitter and Receiver Card

5.2 NORMAL OPERATING CONDITIONS

If the flowmeter is properly installed, the display will begin working when power is supplied to the unit. Two LED indicators—one showing a valid power connection and the other showing the meter is in a "RUN" mode—will illuminate, and the display will show readouts of flow total, flow rate, fluid properties and signal diagnostic information. If more detailed diagnostic data is needed, consider accessing transmitter diagnostic data via the USM Advisor software.

WARNING
Except when troubleshooting, do not remove the enclosure covers from the transmitter. The diagnostic information is easily read from the display with the covers in place.

5.3 DISPLAY LEDS

The typical statuses of the LEDs are as follows. (Refer to Section 7, Troubleshooting and Diagnostics for troubleshooting information.)

Table 5.1 LED Diagnostics

LED Number	Color (typical)	Indication	Normal State
1	Green	Power on	On
2	Green	Operation	On

5.4 DISPLAY

The transmitter has a 400x240 pixel LCD. The display shows the meter's indicated flow rate, totalized flow, fluid properties, and diagnostics data. Parameter values independently scroll across the display in a continuous loop.

Table 5.2 is an illustration of the display content provided and does not reflect the order in which screens are presented on an actual device.

Table 5.2 Display Screens

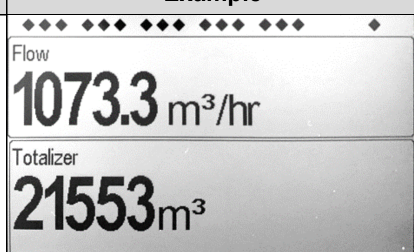
Display Type	Example	Content Description
Main Display		Flow rate and flow totalizer with user-selectable units
Process Properties		Flow rate with process temperature and pressure

Table 5.2 Display Screens

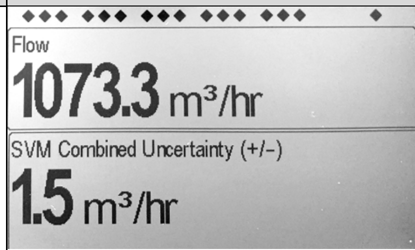
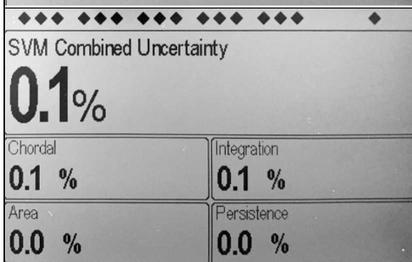
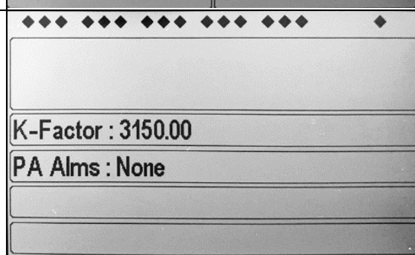
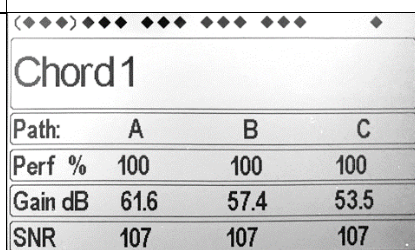
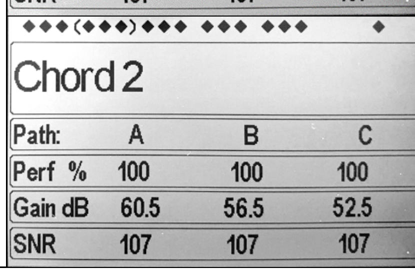
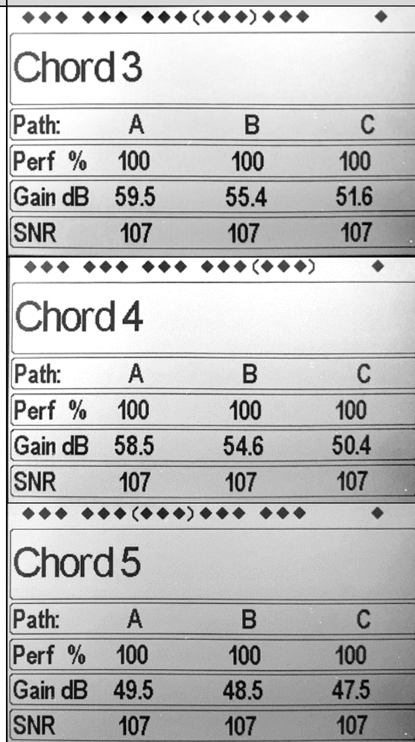
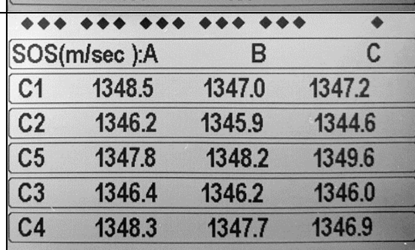
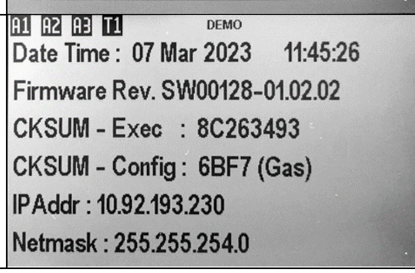
Display Type	Example	Content Description
Measurement Uncertainty		Flow and combined measurement uncertainty viewed in volumetric (m^3/hr) terms
		Combined measurement uncertainty viewed in relative (%) terms
Alarm Summary		Meter K-Factor is displayed. Some alarms require user acknowledgement. These alarms require "Write Protection" to be disabled (see Section 8: Metrological Seals). They include: EXE_CKSUM *Executable checksum* CFG_CKSUM *Configuration checksum* NVRAM *Nonvolatile memory error* WD_RESET *Watch dog reset* OSCTEST *Clock accuracy test failure* PFThresh *Meter performance failure* MBTemp *Meter body temperature out of range*
Path Signal Quality	 	Five screens, arranged by measurement Chord (1-5) and vertical Plane (A-C). The system checks the data quality for ultrasonic paths and evaluates the data against thresholds. Data evaluation is based on signal to noise ratio (SNR), cross-correlation tests, and signal statistics.

Table 5.2 Display Screens

Display Type	Example	Content Description
		
Path SOS		The transmitter displays and checks the consistency of the sound velocities computed by each path.
Software Information		The top row shows analog input measured channels (A1, A2, A3, T1). A black background indicates an out-of-range measurement. Firmware version *Example: SW00128* Revision *Example: 01.02.02* Executable checksum *Example: 8C263493* Configuration check sum *Example: 6BF7*

5.5 ALARM CONDITIONS

The SVM 389 shares the same automatic fault detection system that is common to the LEFM product line and designed to verify the performance of the transducers and transmitter electronics and to alert personnel when abnormal operating conditions are detected. In addition to the features common to the LEFM product line, the SVM incorporates power quantitative uncertainty analysis, providing a powerful yet very easy-to-understand output that describes the measurement accuracy in volumetric and % terms.

Fault detection and uncertainty quantification are carried out in the following steps:

1. The system checks the data quality for ultrasonic paths and evaluates the data against thresholds. Data evaluation is based on signal to noise ratio (SNR), cross-correlation tests, and signal statistics.
2. The transmitter confirms the self-consistency of the sound velocities computed by each path.
3. The transmitter confirms the velocity profile parameters. The parameters are FR (Flatness Ratio), Swirl, Plane Balance (a measure of cross-flow), and AR (Asymmetry Ratio or the balance between the top of the meter and the bottom of the meter).
4. Uniquely, SVM also computes a quantitative evaluation of the measurement uncertainty. This is computed in volumetric terms (m^3/hr) and can also be viewed in relative (%) terms. The primary U-SVM uncertainty output (SVM Combined Uncertainty) is derived from measurement data and a series of calculations for each of the factors contributing to the measurement uncertainty. The U-SVM value is easily understood, and the components contributing to the uncertainty can also be examined to inform fault diagnosis.

Section 6: Maintenance

WARNING
Service should be performed on the SVM 389Ci only by qualified personnel.

6.1 INTRODUCTION

The troubleshooting and maintenance procedures in this section may be incorporated into the customer's standard maintenance program. The procedures should be performed only by a trained maintenance technician. For additional assistance, contact Sensia Technical Support via https://www.sensiaglobal.com/Technical-Support.

6.2 GENERAL INSPECTIONS AND PREVENTATIVE MAINTENANCE PROCEDURES

CAUTION
Wear an ESD protective wrist strap to avoid damaging any components.

WARNING
Never open the transmitter or the transducer covers when the instrument is energized. Before inspecting components, open the power supply circuit breaker. Failure to do so may result in electrical shock and/or an explosion.

The following procedure covers the inspection of the transmitters, transducers, and metering sections.

6.2.1 ELECTRONIC ENCLOSURE INSPECTION

Perform the following inspections on each enclosure bi-annually or according to site guidelines:

1. Verify that the transmitter enclosure and the meter body have suffered no structural damage. Report any damage to the proper maintenance supervisor.
2. Remove dust, dirt, and other soiling from the enclosure. Use a damp cloth to clean surfaces.
3. Remove access covers.
    a. Inspect gaskets. Clean gaskets and mating surfaces on the enclosure with water if they are dirty.
    b. Contact Sensia if there is any corrosion on the mating surfaces.
    c. Verify that gaskets compress when the cover is installed.
    d. Lubricate the cover threads. Use petroleum jelly for aluminum enclosures and use anti-seize for stainless steel enclosures.
4. Inspect the enclosure mounting.

6.2.2 INTERNAL ELECTRONICS INSPECTION

1. Put on an ESD (Electrostatic Discharge) protective wrist strap. Connect the ESD protective wrist strap to a known earth ground.
2. Inspect cable entry points to assure that cable insulation is free from damage.
3. Inspect cable connections for tightness. If connections are fouled or corroded, clean with electronic contact cleaning fluid.
4. Inspect all internal connections and terminals for tightness. If connectors and terminals are fouled or corroded, clean with electronic contact cleaning fluid.

5. Inspect the display for damage.

6.3 TRANSMITTER TROUBLESHOOTING

Perform the following inspections on the transmitter to isolate a problem.

WARNING
Never open the transmitter or the transducer covers when the instrument is energized. Before inspecting components, open the power supply circuit breaker. Failure to do so may result in electrical shock and/or an explosion.

CAUTION
Wear an ESD protective wrist strap to avoid damaging any components.

1. With the unit energized, verify that power is being supplied to the meter and that the meter is operating. When the flowmeter is operating normally, the LEDs (LED 1 & 2) should be illuminated.
2. Always verify that the “Power On” LED (LED 1) is active before troubleshooting a component.
3. Troubleshoot an error condition by checking the following lights in the order listed:
   a. If LED1 is out:
      The power has failed. All the LEDs and the display should be off in this instance. Investigate the cause (e.g., loss of power to site). Another possibility is that extreme power surges damaged the protection circuits in the IOP. Check the IOP for fuses that may be blown and replace as necessary. The IOP also has surge protection circuitry that may be damaged.
   b. If LED2 is out and LED1 is lit:
      The transmitter is powered but not running. Observe the display. If serial or Ethernet communications are functioning, confirm that the device has a valid setup file (Note – the software will not run if the setup file is corrupted.) A bad setup file is annunciated on the display and in the Modbus registers. If the setup file is acceptable, then review the power supply voltages on the MXR and CTC (via Modbus registers). If these power supply values are within specification, then contact Sensia.

6.4 CIRCUIT BOARD REPLACEMENT

The transmitter comprises three basic subassemblies. Refer to Table 6.1 for a description of each subassembly’s components.

Table 6.1 Circuit Boards

Circuit Board Name	Description/Function
Input/Output and Power Supply (IOP)	Provides galvanically isolated digital outputs, analog output/input and communications. Converts 24 VDC/120/240VAC power to internal voltages, which are passed to the CTC/MXR to power the electronics. Provides fused connection to power (Fuse F25).
CTC and Display	Performs all flow meter processing. Contains the display and communicates with the MXR and IOP.
Multiplexer, Transmitter and Receiver (MXR)	Interfaces with transducers, excites and receives acoustic signals.

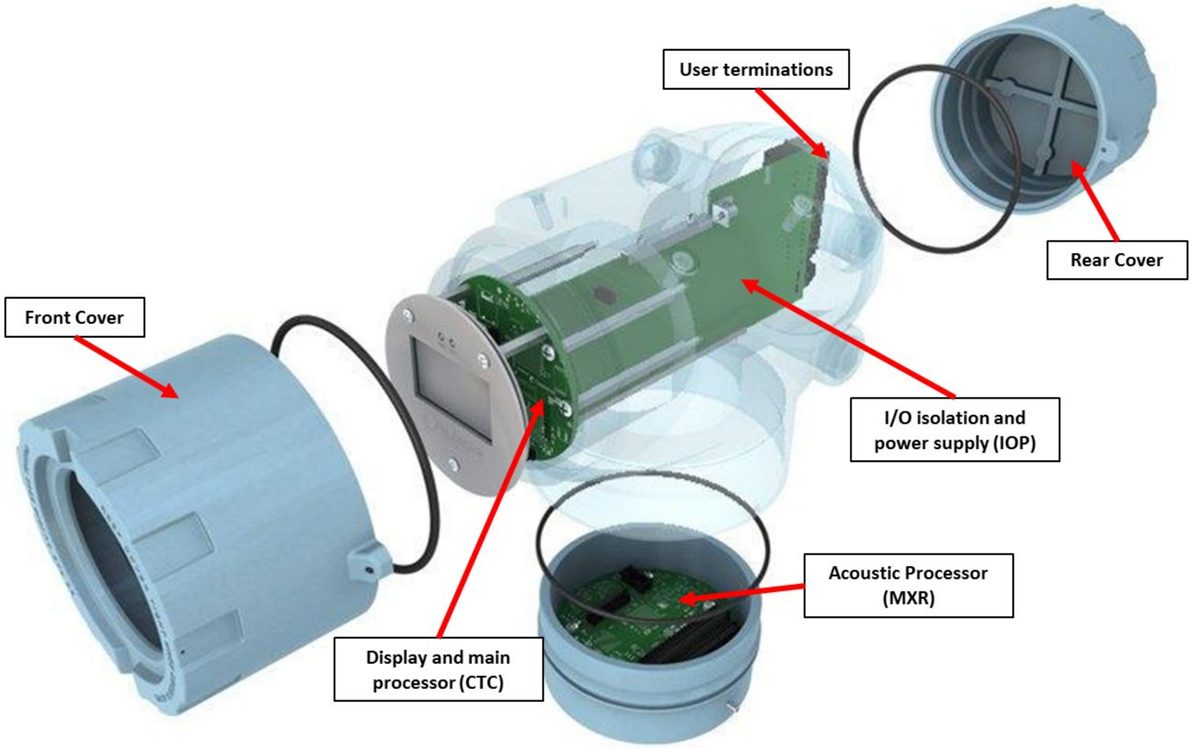


Figure 6.1—Transmitter components

6.4.1 IOP – INPUT/OUTPUT AND POWER SUPPLY BOARD OR POWER FUSE REPLACEMENT

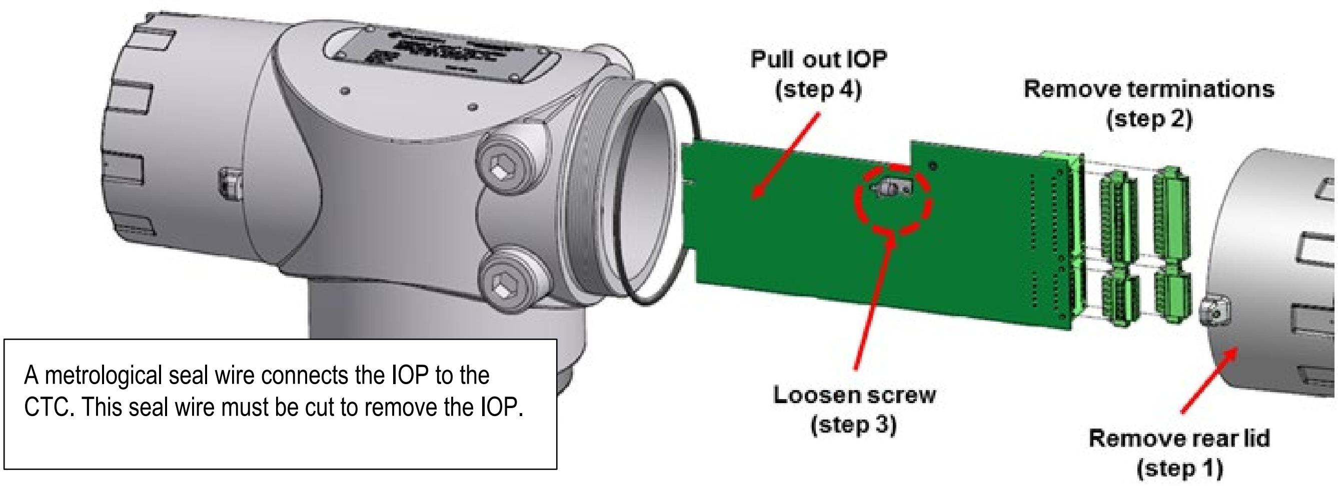


Figure 6.2— Disassembly views for IOP replacement

> **WARNING**
> Never open the transmitter when the instrument is energized. Before inspecting components, open the power supply circuit breaker. Failure to do so may result in electrical shock and/or an explosion if in a hazardous area.

If any component on the IOP assembly fails (other than the fuse), you must replace the entire assembly as described below, referring to Figure 6.2 for hardware locations.

1. Loosen the 2mm hex set screw on the rear enclosure. Unscrew and remove the rear lid of the enclosure.

> **CAUTION**
> Personnel handling circuit boards must use proper grounding straps to prevent damage from electrostatic discharge.

2. Remove all user terminations or terminal blocks such that the board can be fully accessed.
3. Remove the enclosure’s front cover as described in section 6.4.2 CTC and Display Replacement, page 42, and cut the plastic metrological seal wire connecting the IOP to the CTC.
4. When viewing the transmitter from the back, a screw that holds the IOP to the enclosure can be seen towards the top of the IOP. Loosen the screw until it is disengaged (it is a captive screw).
5. Grasp the edges of the IOP and gently pull it out of its connection with the CTC board. If ONLY the IOP fuse needs to be replaced, proceed to the next step. If the entire IOP needs to be replaced, skip to step 8.
6. Locate the IOP/F25 fuse. (Note – the fuse protects the electronics from errant wiring of power to 120/230 VAC). The F25 fuse is on the same side of the IOP board as the plug-in connectors, near the power inputs (TB1). Refer to Figure 6.3 below.

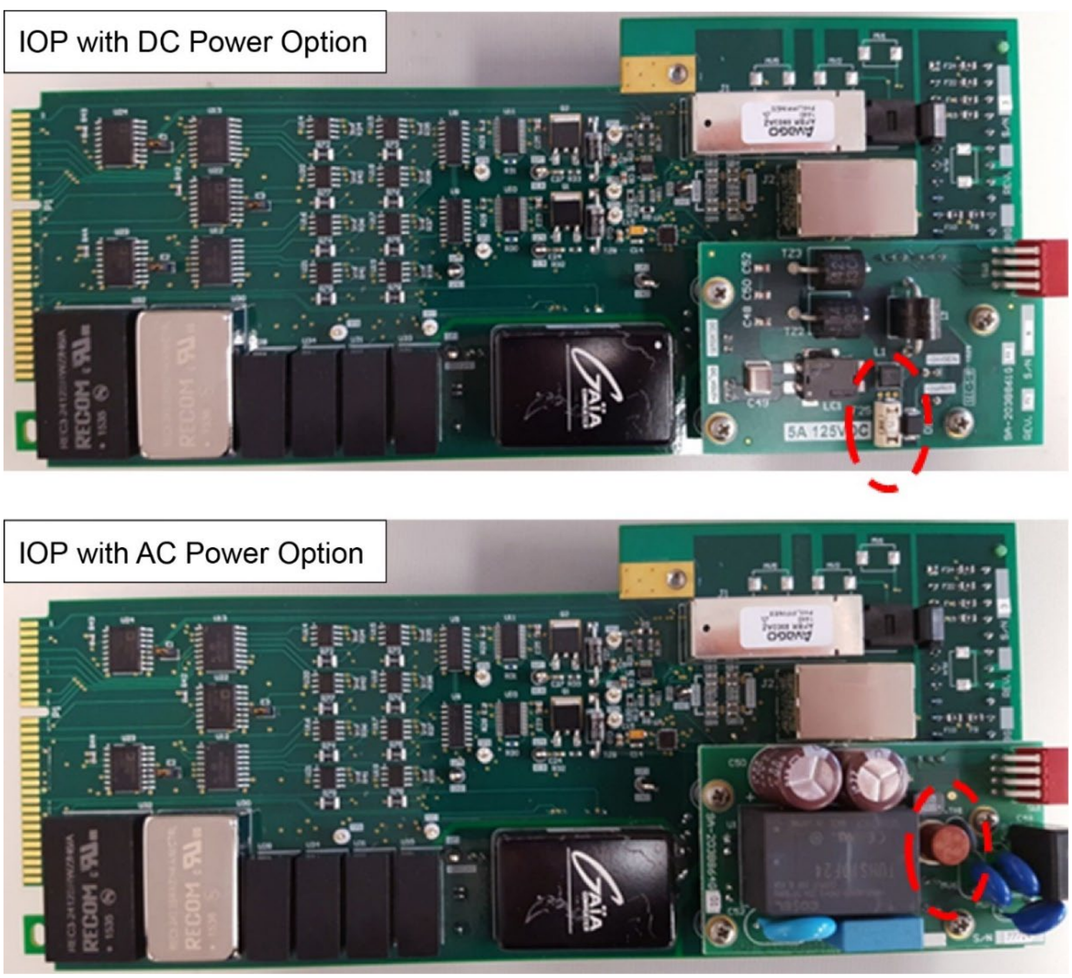


Figure 6.3—Location of IOP/F25 fuse

7. Remove the F25 fuse with tweezers or needle nose pliers and replace it with a new fuse.
   - DC Option: Only use Littelfuse Series part number 0454-005 (5 amp rating) as a replacement fuse. Skip to step 9.
   - AC Option: Only use Littelfuse Series part number 37412000430 (2 amp rating) as a replacement fuse. Skip to step 9.
8. Remove the new IOP from its packaging and place the old IOP into this packaging for proper storage.

Important Make note of which IOP version is installed. This is important because if the IOP is set to "FX" the CTC may also need to be replaced when the replacement IOP is the 9A-204B169 version. See **Remote Data Communications**, page 27, for additional information.

9. Align the IOP with card guides. Slide the IOP down the guides until it engages the connector of the CTC. Firmly push the IOP so that the connector seats (DO NOT FORCE).
10. Install a new plastic metrological seal wire connecting the IOP to the CTC.
11. Replace the enclosure's front cover as described in section 6.4.2 CTC and Display Replacement, page 42.
12. Viewing the transmitter from the back, tighten the screw that holds the IOP to the enclosure.
13. Reattach all user terminations or terminal blocks. Confirm that all connectors' flanges are tightened and all terminations are secure.
14. Screw the rear lid of the enclosure back on. This should be hand tight with at least eight full turns of the lid. Tighten the set screw on the lid.

6.4.2 CTC AND DISPLAY REPLACEMENT

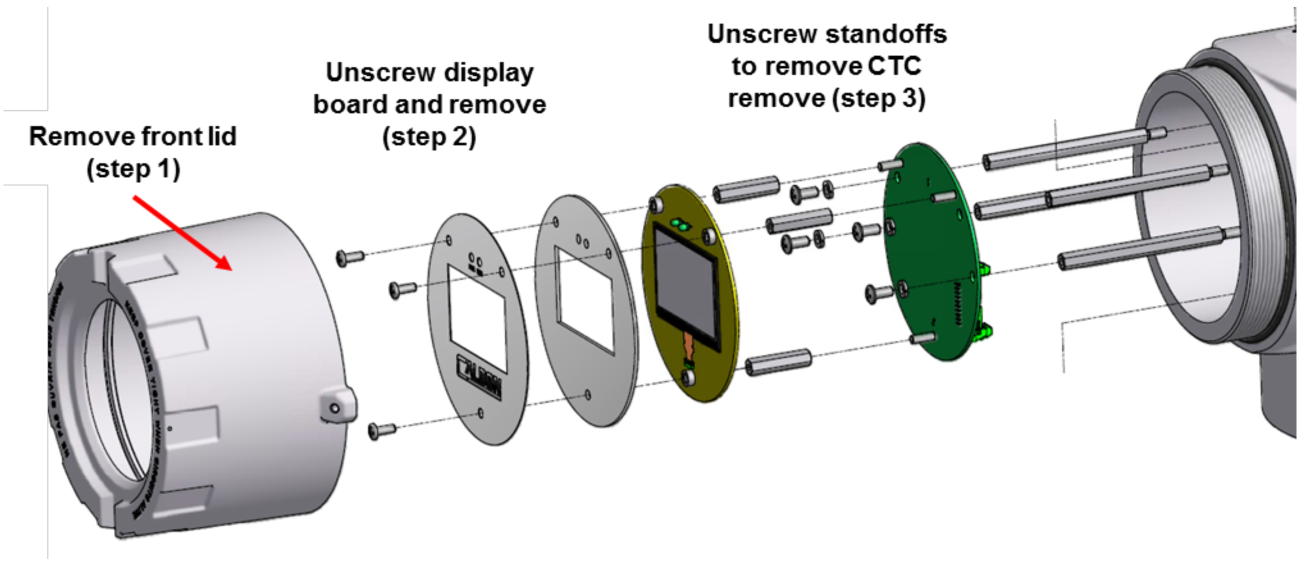


Figure 6.4—Disassembly views for CTC and display replacement

WARNING

Never open the transmitter when the instrument is energized. Before inspecting components, open the power supply circuit breaker. Failure to do so may result in electrical shock and/or an explosion if in a hazardous area.

WARNING

The transmitter has a real time clock that has battery backup. It is recommended to replace the complete circuit board if the battery ever fails. Do not replace the battery alone. It must be replaced with the identical battery and it must never be changed in a hazardous location area.

The CTC and display assembly consists of two component boards that are not designed for replacement individually. If any component on the CTC and display assembly fails, the entire assembly is to be replaced.

To replace the CTC and display assembly, perform the following steps, referring to Figure 6.4 for hardware locations.

1. Loosen the 2mm hex set screw on the front enclosure. Unscrew and remove the front cover from the transmitter.

CAUTION

Personnel handling circuit boards must use proper grounding straps to prevent damage from electrostatic discharge.

2. Unscrew the display board from the CTC. Grasp the edges of the display and gently pull to lift it from the CTC. If the display is faulty, discard it and skip to step 6. Otherwise, put it into an anti-static bag for later use.
3. Unscrew the four screws to free the CTC assembly from the transmitter body and lift the assembly from the enclosure. On the rear of the CTC, disconnect the ribbon cable from connector P1.
4. Cut the plastic metrological seal wire connecting the IOP to the CTC.
5. Remove the new CTC from its packaging and place the old CTC into this packaging for proper storage.

Important Make note of which CTC revision is installed. Revision 07 has implemented DIP switches to change what network communication is being used. SW3 in the upper left-hand corner of the assembly allows the user to change between copper and fiber termination when using a legacy IOP. All of the switches must be in a line to ensure proper communication. The default position is “CU”. If the fiber communication is required, slide all switches to the “FX” position.

Note SW3 should be set to “CU” when used with the 204B169 IOP regardless of copper (Cu) or fiber usage (Figure 6.5, page 44).

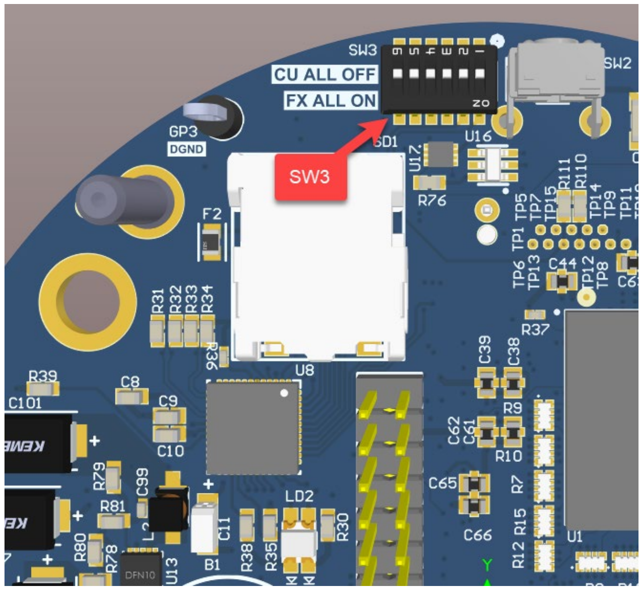


Figure 6.5—SW3 setting for use with a 204B169 IOP

6. Connect the ribbon cable to the back of the CTC card. Gently press the CTC assembly onto the IOP connector. Refer to Figure 6.6 below for a view of the routing path.
7. Install a new plastic metrological seal wire connecting the IOP to the CTC.

CAUTION
Ensure the ribbon cable is routed to the right side of the IOP board when viewed from the CTC end of the enclosure. If not routed properly, the ribbon cable can get pinched by the IOP/CTC connector.

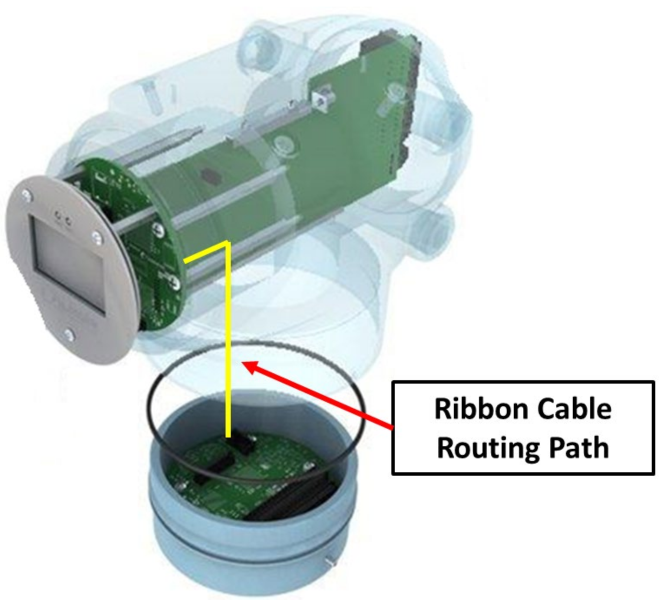


Figure 6.6—MXR-CTC ribbon cable routing path

8. Reinstall the four screws that were removed in step 3, screwing them into the holes provided in the CTC board.

9. Reattach the display by aligning the connector on the rear of the display board to connector P2 on the CTC.
10. Reinstall the three screws that secure the display board to the CTC.
11. Screw the front lid of the enclosure back on. This should be hand tight with at least eight full turns of the lid. Tighten the set screw on the lid.

CAUTION
Following replacement of the CTC board, the “safe mode” readout may appear in the transmitter display. This is an indicator that the configuration data has not been uploaded to the transmitter. See section 7.1.1.2 Reprogramming the Transmitter, page 52, for instructions on downloading the configuration file.

6.4.3 MXR REPLACEMENT

WARNING
Never open the transmitter when the instrument is energized. Before inspecting components, open the power supply circuit breaker. Failure to do so may result in electrical shock and/or an explosion if in a hazardous area.

If any component on the MXR assembly fails, the entire assembly must be replaced. To replace the MXR, perform the following steps, referring to Figure 6.7, page 46, for hardware locations.

CAUTION
Personnel handling circuit boards must use proper grounding straps to prevent damage from electrostatic discharge.

1. Disconnect the ribbon cable from the CTC card by following section 6.4.2, CTC and Display Replacement, steps 1 through 3, page 42.
2. Disconnect any conduit attached to the transmitter.
3. Loosen and remove the two set screws on the top of the enclosure as shown below. Unscrew and remove the top portion of the enclosure.

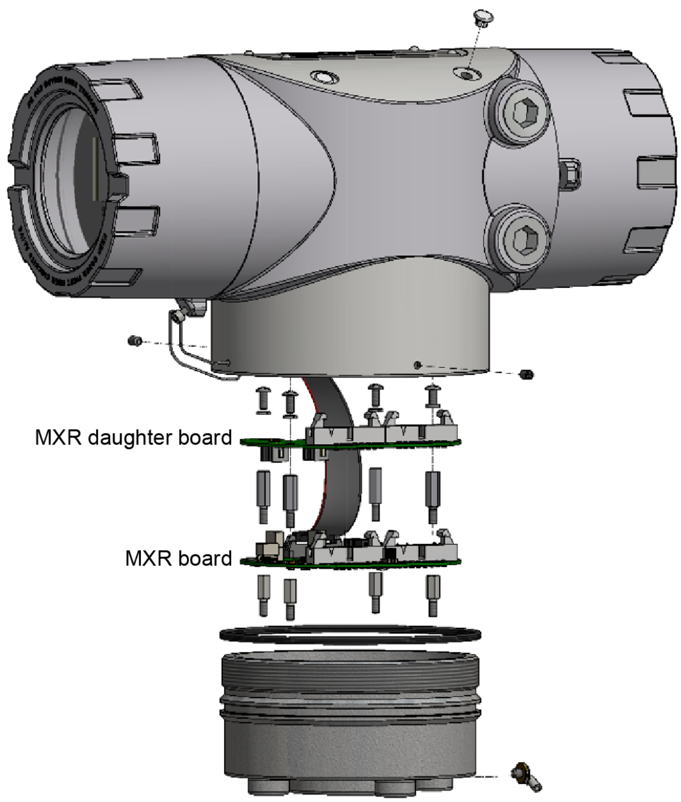


Figure 6.7—Disassembling the transmitter to access the MXR

4. Remove the MXR daughter board as follows.
   a. Loosen the transducer wires ribbon cables on the MXR daughter board (two connectors) and disconnect both connectors. Push the transducer wires/connectors to the side so that the MXR daughter board can be removed, marking the cables for reassembly.
   b. Remove the four MXR daughter board fasteners. Grasp the edges of the daughter board and gently pull to lift it from the MXR.
5. Remove the MXR board as follows.
   a. Loosen the transducer wires ribbon cables on the MXR board (two connectors) and disconnect both connectors. Push the transducer wires/connectors to the side so that the MXR board can be removed, marking the cables for re-assembly.
   b. Remove the ribbon cable from the P1 connector.
   c. Remove the four hex standoffs and lift the MXR from the enclosure.
6. Remove the new MXR / daughter board from its packaging and place the old MXR board(s) into this packaging for proper storage.
7. Align the MXR with the standoffs in the bottom of the enclosure and reinstall the four standoffs that were removed in step 5b.
8. Reattach the ribbon cable and the transducer wire connectors.
9. Replace the four stand-offs and replace the daughter board and ribbon cables, ensuring the cables are returned to the same connector as before and are not pinched between the boards or between the boards and the enclosure.
10. Replace the four screws that hold the daughter board in place.

11. Screw the top portion of the enclosure back on with at least eight full turns of the enclosure. Once fully threaded on, reinstall the set screws. Turn the enclosure to face the proper direction and tighten the set screws.

Note	The set screws can only fully tighten if the enclosure has been threaded to the bottom range of its threads.

12. Reconnect the ribbon cable to the CTC by following section 6.4.2 CTC and Display Replacement, steps 5 through 9, page 42.

6.5 TRANSDUCER INSTALLATION

WARNING
Do not attempt replacement of a transducer without technical guidance from Sensia. Contact Sensia technical support at https://www.sensiaglobal.com/Technical-Support.

WARNING
Never open the transmitter when the instrument is energized. Before inspecting components, open the power supply circuit breaker. Failure to do so may result in electrical shock and/or an explosion if in a hazardous area.

Transducer failure is highly unlikely under normal circumstances. However, in the event of transducer failure, the following procedure can guide you through the step-by-step installation process.

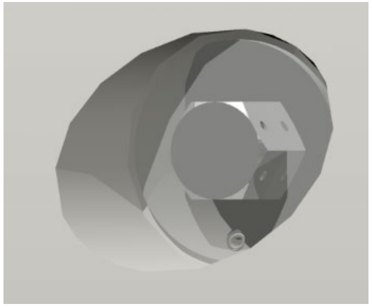


Figure 6.8—Transducer housing access cover

1. Remove the tamper evident seal if one exists.
2. Remove the transducer housing access cover (Figure 6.8) with a ¾” [19 mm] socket. Disconnect the failed transducer’s wire terminations.
3. Remove the transducer internals using a pass-through socket head (½-in. socket). Use a press and twist motion to disengage the compression nut (Figure 6.10, page 48).

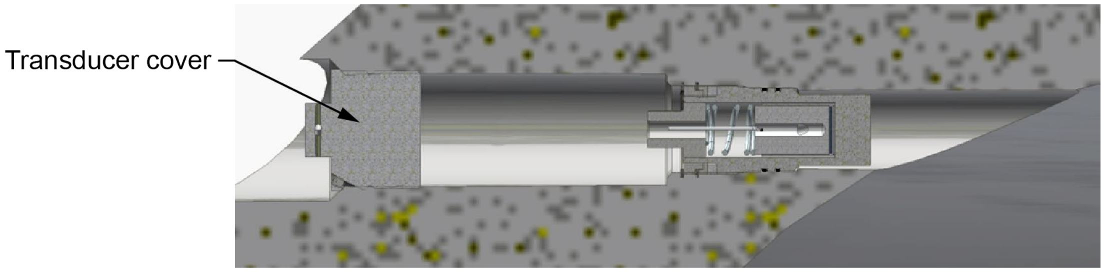


Figure 6.9—Transducer housing cross-section

WARNING
Never tamper with the transducer housing (shown in Figure 6-10). The housing is pressurized and contains two locking rings to keep the housing in place. Only Sensia technicians may remove these pressure-containing components.

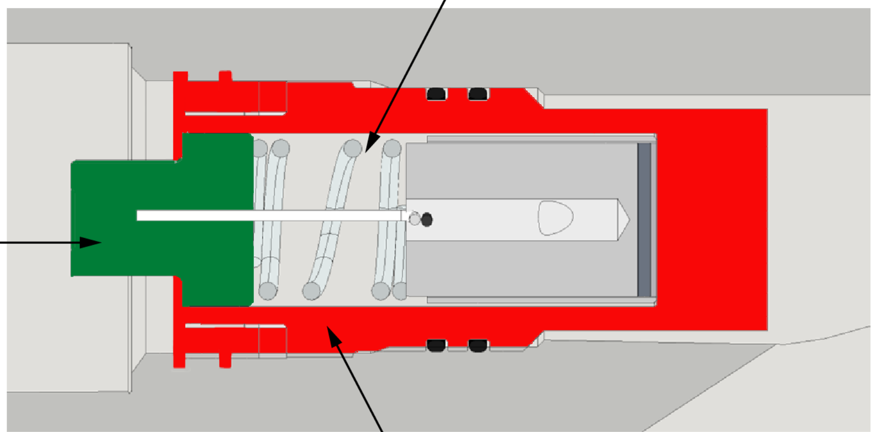


Figure 6.10—Transducer housing detail

4. Remove the failed transducer.
5. Visually inspect the transducer housing and verify it is clean and free from dirt and old couplant.
6. Re-install the transducer internals as follows.
   a. Thread the wires of the transducer though the compression spring and compression nut.
   b. Apply transducer couplant to the transducer face.
   c. Insert the transducer and components into the housing until the parts bottom out.
   d. Using the pass-through socket, press the compression nut in and turn to lock. This will energize the spring.
7. Connect the wires of the new transducer.
8. Re-install the transducer housing access cover.
9. Replace tamper evident seals as required.

Note The SVM 389 system may require verification of acoustic performance when a transducer is replaced or re-coupled (see Section 7, Troubleshooting and Diagnostics).

6.6 ANALOG INPUT VERIFICATION

The SVM 389 may have an analog input (for example, temperature, pressure, or density). The input signal is conditioned before it is converted to a digital input.

The input is scaled linearly to convert the user input of 4-20 mA to maximum and minimum values of the engineering units. Analog input ranges can only be adjusted via the USM Advisor software interface (see the USM Advisor manual for instructions).

Failed inputs result in readouts at their lowest range. For example, a 4-20 mA pressure input scaled to 0-1000 psig will go to 0 psig if the input is removed.

6.7 ANALOG OUTPUT AND PULSE OUTPUT VERIFICATION

The digital output channels consist of an analog output and a pulse output. The current output channel has a 4-20 mA range. The pulse output has a range of 0 to 5V or 0 to 12V. There are no adjustments to be performed for the analog or pulse outputs. The analog output can be mapped to any Modbus input register for maximum flexibility. By default, the analog output is mapped to read flow.

6.7.1 FORCE OUTPUT (ANALOG)

The analog output is scaled linearly between its maximum and minimum values. Use the force output function of USM Advisor software to test the scaling of the analog output with input site devices. (See the USM Advisor Manual for detailed instructions.)

6.7.2 FORCE OUTPUT (PULSE)

Similar to calibrating the analog outputs, a fixed frequency may be forced out of the transmitter pulse output. To verify the pulse output using a forced output, follow the instructions in the USM Advisor Manual.

Section 7: Troubleshooting and Diagnostics

7.1 DIAGNOSTICS

The SVM transmitter display provides basic diagnostic information. More detailed diagnostics are available via software download with serial ports or an Ethernet port. The transmitter's serial and Ethernet ports use the Modbus protocol. Sensia's CALDON USM Advisor software allows the user to interface with the transmitter via the serial port or Ethernet port.

Note Modbus registers can be edited to change the configuration of many SVM parameters. However, these instructions are outside the scope of this manual. Throughout this section, values such as path SNR (Signal to Noise Ratio), Gain, etc. are discussed in reference to the CALDON USM Advisor software. See Modbus manual IB1504 for Modbus register addresses.

In addition to an extensive list of signal, flow and process related diagnostics, SVM flowmeters evaluate measurement uncertainty in quantitative terms and provide that information via Modus and to the USM Advisor software.

The primary output, the SVM Combined Uncertainty or U-SVM, describes the uncertainty in the meter's volumetric output and can be displayed in volumetric or percentage terms, and can be monitored relative to warning and alarm limits. Lower-level uncertainties (for velocity measurement, flow profile, area and persistence terms) can also be viewed to provide understanding of the sources of uncertainty contributing to the U-SVM value.

The following screen capture depicts the USM Advisor interface software showing the uncertainty view in the bottom left graph. Please refer to the software manual for more information.

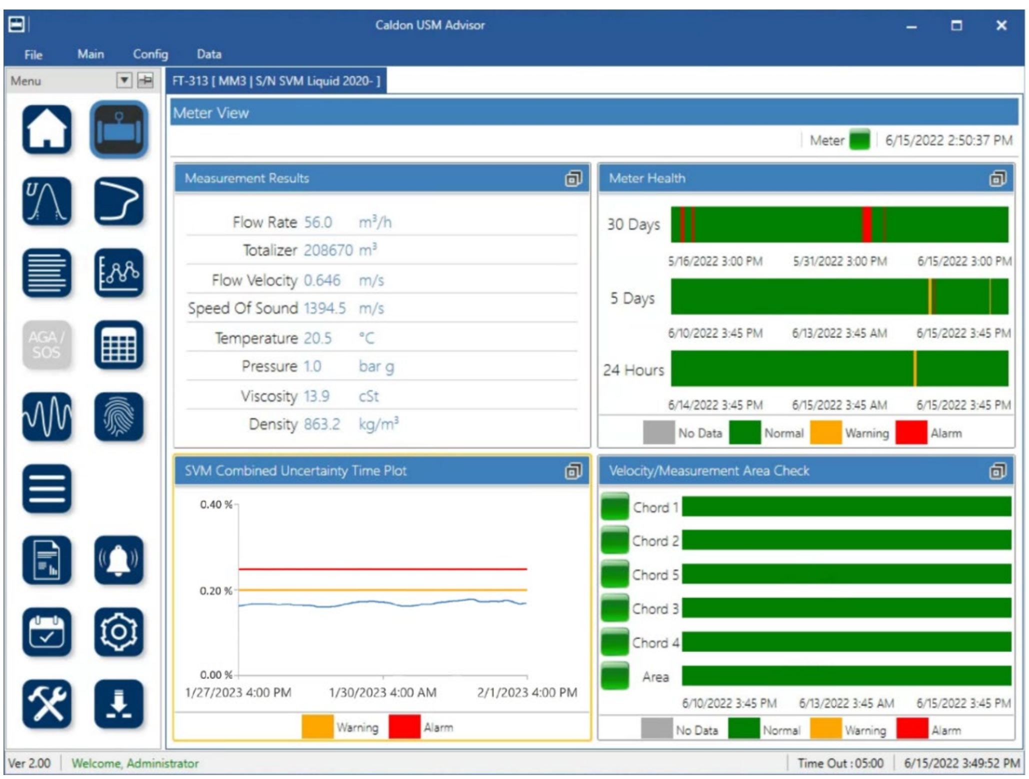


Figure 7.1—Diagnostic screen

For troubleshooting ultrasonic signals, the most frequently used diagnostic parameters are shown below in Table 7.1.

Table 7.1 Signal Diagnostics

Diagnostic Parameter	Typical Values for Normal Operation
Performance (% Good)	90 to 100%
Gain	20 to 60dB
SNR	20 to 999

7.1.1 AUTOMATIC FAULT DETECTION

The SVM transmitter continuously checks the data quality of each ultrasonic path for detecting faults. Each time the signal is sampled, the transmitter tests the signal as follows:

1. The transmitter checks the quality of data collected from the ultrasonic signals and evaluates it against pre-set thresholds. The data is evaluated based on SNR, cross-correlation tests, and signal statistics.
   - The transmitter verifies whether the path's SNR is higher than its threshold value.
   - The transmitter correlates the upstream signal with the downstream signal to test for "cycle skipping." The processor rejects data that does not pass this correlation test.
   - The transmitter verifies the computed transit time and Delta T are acceptable.

Note The transmitter will reject data occasionally; this will not influence the operation. If an ultrasonic path rejects data continuously, the SVM will alert the operator with an "ALARM" status and an error code.

2. The processor outputs the individual path status codes through a digital output and Modbus. USM Advisor software interprets these codes and displays a text message. The individual path status codes are:
   - 0 = Path is operating normally.
   - 1 = Invalid. The processor is still searching and validating data for the path.
   - 2 = Pre-valid. The processor is still searching and validating data for the path.
   - 5 = Path sound velocities are inconsistent with thresholds. (Typically, up to 0.2% spread between paths is acceptable.)
   - 7 = Path velocity is inconsistent at low flow rates.
3. The processor outputs the current meter status through a digital output and Modbus. The meter status is identified as one of the following:
   - NORMAL. Status bit at 5 volts or 12 volts.
   - ALARM. One or more paths have failed; flow is computed with a lower accuracy (status bit is at 0 volts).

     The software can be configured to go to zero flow when only one or two paths function.

7.1.1.1 Path Status

When the path status indicates a failure ("Invalid" or "Pre-Valid"), the percentage of data that has been accepted is below SVM thresholds. Use the following troubleshooting sequence to pinpoint the cause:

1. Verify that the meter body is pressurized. If there are liquids in the line, bottom paths may fail.
2. Verify the continuity of all cable connections.

3. Check the display. If the display reports “Configuration File Needed” or “Flowmeters,” the transmitter needs to be reprogrammed or the CTC board requires replacement (see section 6.4.2, CTC and Display Replacement, page 42).
4. Check the ultrasonic signal. Check path gains via Modbus or USM Advisor software. If the path gains are high (65dB or higher), the signals may be too weak to be detected. Weak signals can be caused by any of the following (listed from most likely to least likely):
   - The line contains liquid.
   - The cable/wire from the meter to the transmitter is damaged.
   - The transducer has failed.
5. Check the transducers for failure. The SVM has a diagnostic capacity for determining which transducer(s), if any, needs attention. Normally, the gains for the upstream and the downstream are equal. However, if a transducer fails due to wiring, coupling, etc., one transducer will have a higher gain. Follow these steps to determine which transducer has failed:
   a. Review the SNR for each path (paths 1 through 15). The SNR should be greater than 40 (or greater than 20 for low pressures).
   b. Review the gains for each path (both upstream and downstream). The gains should be between 10dB and 85dB. Upstream and downstream gain should nominally be within 3 dB of each other.
   c. Review the Performance (percentage of good data) for each path. The percentage should be between 90% and 100%.

Remember the following troubleshooting tips:

- If all paths fail, the meter has low pressure, the meter has significant liquid, or an electronics hardware failure has occurred.
- If a path has Performance = 0% good data, the transmitter cannot lock onto a signal. The cables or transducers should be investigated for potential failure.
- If an ultrasonic signal does not exist, or if SNR has degraded from installation, follow this checklist:
  - Verify the pipe contains no liquid.
  - Check the continuity of transducer cable.

7.1.1.2 Reprogramming the Transmitter

Before each transmitter leaves the factory, it is pre-programmed to work with the meter body with which it will be installed. This information is stored within a configuration file that is maintained by Sensia. The file includes the following information:

- Pipe size
- Pipe transducer frequency
- Ultrasonic path lengths
- Calibration constant
- Alarm settings
- K-Factor
- Analog input/output scaling

Should the processor in the transmitter fail and require replacement, reprogram the transmitter with the appropriate configuration file using USM Advisor software (for PC). The procedure is as follows:

1. Download the USM Advisor User Manual from Sensia’s website for reference.
2. Connect the serial interface cable to the transmitter and a COM port on the PC.
3. Select the appropriate Modbus ID and baud rate using USM Advisor software. All transmitters are initially programmed with a Modbus ID of 1, and a baud rate of 19200 with RTU Slave Mode.
4. Select the configuration file for the meter.
5. Send the configuration file. The transmitter will be reprogrammed.

Section 8: Metrological Seals

CAUTION

The physical properties, configuration settings, and calibration of the meter body are pre-programmed into the transmitter; therefore, the programming of the transmitter must be controlled. Failure to control transmitter's programming can result in erroneous flow measurements outside the stated accuracy.

As a precaution against tampering the SVM 389Ci design allows for seals to control programming of the transmitter or alterations to the meter body.

To ensure control of the electronics programming, a switch on the CTC board (front of the transmitter) can be engaged, preventing configuration changes. The transmitter with the cover removed is shown in Figure 8.1. If the switch SW1-4 (top-most switch) is in the left position (closed), the transmitter is write-protected, and the parameters cannot be reprogrammed (irrespective of passwords). Using this switch together with the seal wire on the transmitter or seals on the circuit boards enables full metrological control of the system.

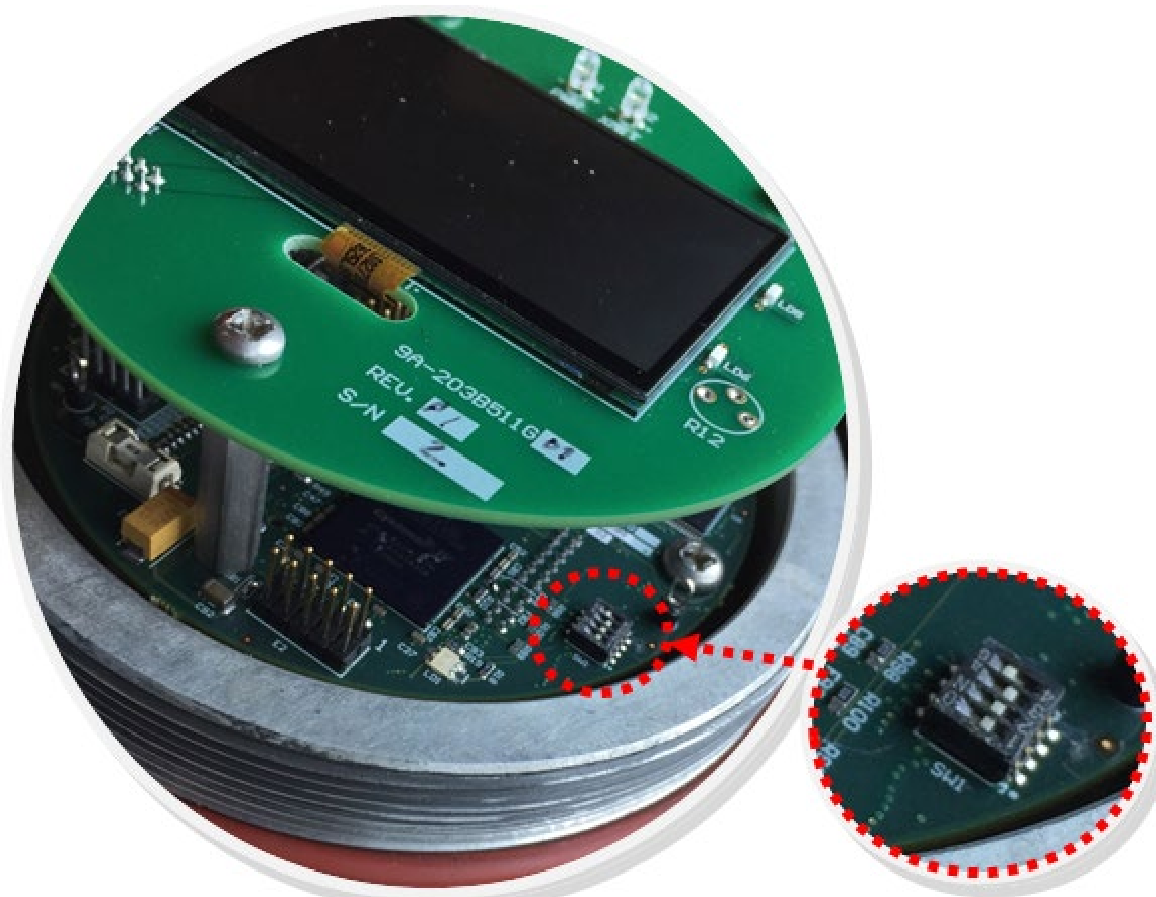


Figure 8.1—Transmitter with CTC switch enabled to prevent configuration changes (shown without tamper evident seal for clarity)

Figure 8.2, page 54, shows the optional seal wire on the transmitter (wire goes from the front cover to the center hub). This seal can be applied by the user if desired. The rear entry can also have an optional seal wire attached (see Figure 8.3, page 54).

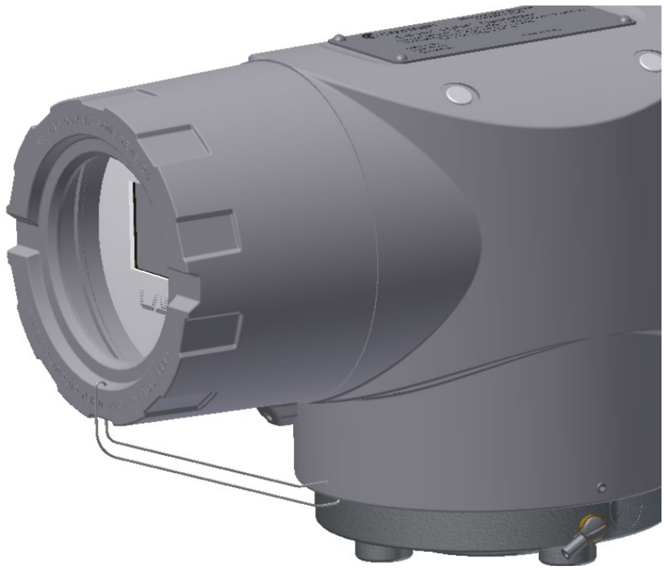


Figure 8.2—Seal wire on transmitter enclosure

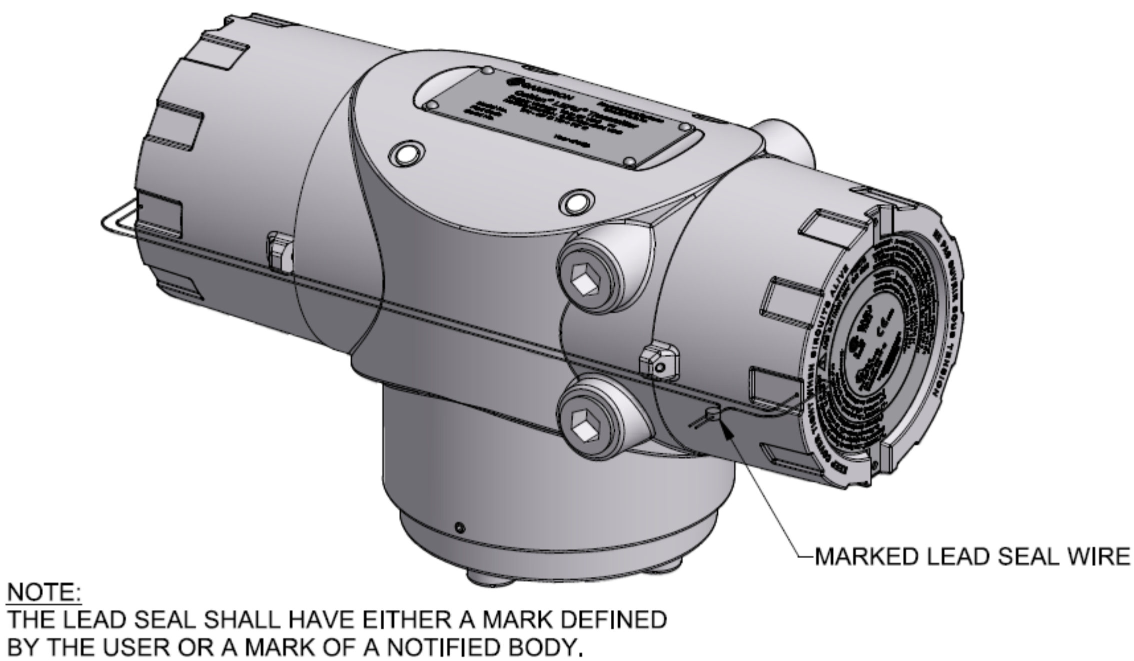
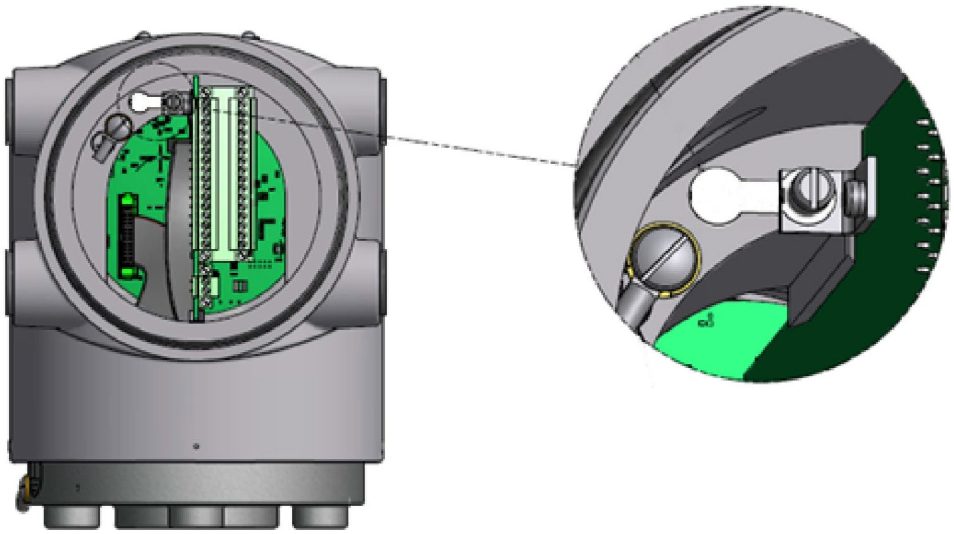


Figure 8.3—Seal wire on both ends of a transmitter

Even when a seal wire is not installed, each of the accessible circuit boards has tamper evident seals. Figure 8.4, page 55, shows the locations of the two tamper evident seals on the IOP.



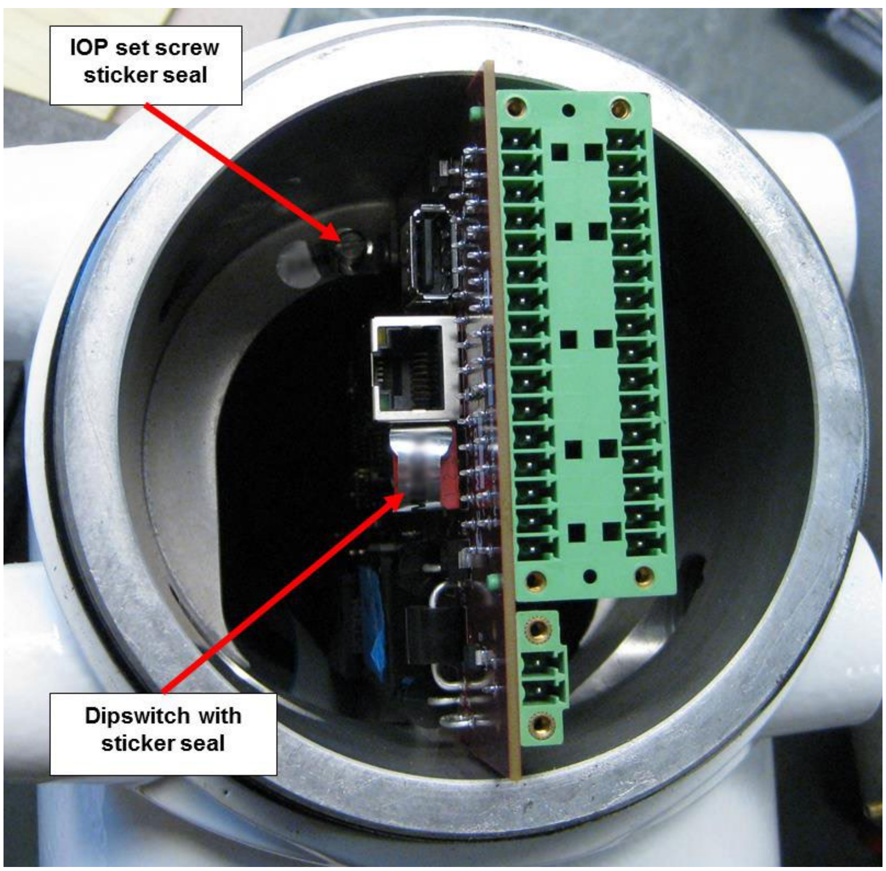


Figure 8.4—IOP tamper-evident seals

Further, the meter body has a seal wire on the fasteners for the transducer cover. The seal wire allows the meter owner to verify if there has been any tampering with the meter body. Refer to Figure 8.5, page 56.

Figure 8.5—Seal wire on meter body

Section 9: Recommended Spare Parts

Figure 9.1—Transducer Equipment

Qty	Description
2	Transducer (appropriate size and frequency)
1	Transducer Grease (small tube)

Figure 9.2—Electronic Equipment

Qty	Description
2	Display Board
1	CTC Board
1	IOP Board
1	MXR Board
1	MXR Daughter Board
1	Transducer Interface Board

Note The printed circuit boards contain electrolytic capacitors. To ensure proper operation of these components, perform a functional test on them at least once every 5 years. Contact Sensia for instructions.

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