Mechanical and Fluidic Integration of the FLS110

Introduction

The FLS110 is designed to be integrated into high volume products with injection moulded flow paths at the lowest system cost. This technical note is concerned with integrating the sensor into your product flow path so that you achieve good mechanical reliability and flow sensing performance. It discusses in some detail different methods of achieving an air-tight seal between the FLS110 and the flow path. It also covers strain relief and effective positioning of the sensor.

The advantages and disadvantages of each method are discussed. All processes proposed here can be easily and reliably implemented in high-volume electronic production assembly lines.

Contents

References

[1] Developing Your Flow Sensing Solution with FLS110 (FL-000986-TN)

[2] FLS110 Miniature Gas Flow Sensor Datasheet (FL-000038-DS)

[3] FLS110 External Geometry STEP file (FL 000732 DW)

[4] FLS110 Pocket Geometry STEP File (FL-001195-DW)

[5] FLS110 System Characterisation and Calibration (FL-000561-TN)

1 Location of the FLS110 in a fluidic system

1.1 Place the sensor as far as possible from sources of turbulence

Turbulent and swirling flow can increase the noise on the flow measurement made by the FLS110. Turbulence and swirl can cause the flow at a location to vary rapidly above and below the bulk flow rate. The FLS110 can resolve these fluctuations and its signal will change rapidly. If the desire is to measure only the bulk flow these rapid fluctuations represent unwanted noise that must be averaged out. This averaging will increase the response time of the sensor to rapid changes in the bulk flow.

To minimise this problem the FLS110 should be placed as far as possible from sources of turbulence such as pumps, fans and changes in flow path cross section or direction which could cause the flow to separate from the walls of the flow path.

In applications with high flow rates the flow in the system may be fully turbulent. Even in this instance the sensor should be placed away from pumps, fans or sudden changes in flow path geometry as these features will temporarily increase the intensity of the turbulence in the flow.

1.2 Make use of existing pressure drops to divert flow through the FLS110

The FLS110 is typically implemented in a bypass configuration and a pressure drop element is used to divert a small percentage of the flow through the sensor in order to make a measurement. Where possible, the overall system pressure drop can be reduced by using an existing source of pressure drop (e.g., a filter or other restriction) as the pressure drop element for the FLS110.

When using a filter to divert flow through the FLS110 be aware that the flow through the FLS110 will remain unfiltered. Levels of dust significantly above normal indoor air (15µg/m^3 PM2.5) may also adversely affect the performance of the sensor over time.

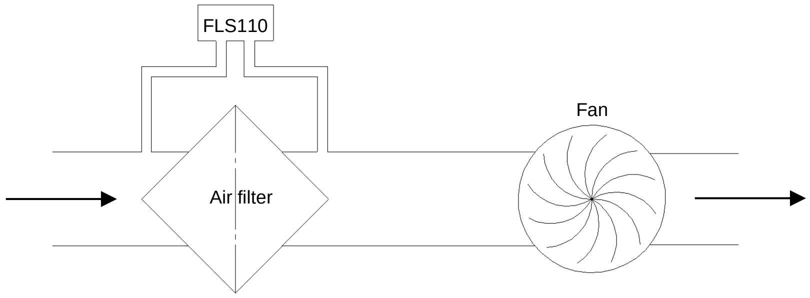

Figure 1: Schematic showing the placement of the FLS110 across the filter of an air purifier

1.3 Characterise the system with the FLS110 in situ

In many applications the FLS110 cannot be installed after long straight pipe runs where flow can be expected to be fully developed. It is important that the system be characterised with the sensor in situ. This allows the system characterisation process to account for phenomena related to system geometry. The FLS110 can then report system flow accurately even for small systems with intricate flow path geometry. This topic is covered in more detail in technical note FLS110 System Characterisation and Calibration.

2 Mechanical integration

A mechanical model for the FLS110 sensor in STEP format is available to assist with CAD modelling of your flow path assembly (FL-000732-DW FLS110 External Geometry STEP file). You can download it from the Flusso customer portal.

The FLS110 is assumed to be mounted on a rigid substrate such as printed circuit board. The recommended approach to making a mechanical interface between the FSL110 and your flow path is to have

- A pocket in your flow path wall to accommodate the FLS110 body (typically 4.2 x 4 x 1.6mm)
- Circular holes at the bottom of the pocket for the FLS110 ports (typically 1.2mm ID)

We have a mechanical model of a pocket (FL-001195-DW FLS110 Pocket Geometry STEP File) that you can download from the Flusso customer portal. We used this design for the FLS110 Evaluation Kit fluidic fixtures – it could be a useful starting point for your own design.

Figure 2 illustrates the FLS110 sitting in a pocket in the flow path wall, seen through the PCB that it is mounted on.

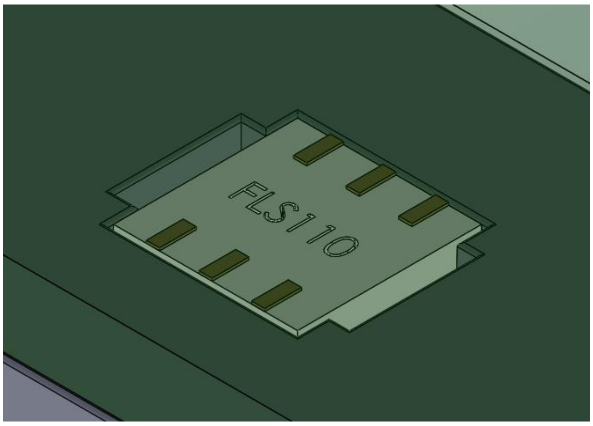

Figure 2: FLS110 located in a pocket in the fluid path wall

A pocket is a good approach as it locates the FLS110 directly. If the FLS110 is located using mechanical features on the PCB or elsewhere, care must be taken to understand the effect of tolerances in the forming of those features and the tolerance of the relative position between them and the FLS110. A close fit in the pocket around the sensor is preferable because it helps with alignment of the FLS110's ports to the holes in the fixture when inserting. The clearances you will have to allow around the sensor will depend on the tolerances of the manufacturing process of the pocket and the tolerances of other alignment features and requirements on your PCB. We suggest a clearance of 0.05mm around the package to ensure good locational accuracy with precision moulded plastic parts.

If the FLS110 is located as shown using a pocket, sufficient clearance should be allowed for other features which might influence the position of the PCB. If using screws (see Figure 6) this is easily achieved by slightly oversizing the holes in the PCB allowing the FLS110 to define the position. Once the screws are tightened down friction between the screw head and the PCB will prevent further movement and provide strain relief. Oversized holes are also suitable for heat staking providing the formed stake holds the PCB tightly. If plastic clips are used, they must be designed to manage the tolerance stack from the FLS110 to the locating features for the clips on the PCB.

Location in the Z-axis is best achieved by reference from the surface of the PCB on which the FLS110 is mounted. Figure 4 shows the PCB contacting the surface of the flow path which locates the FLS110 in the Z-axis. **The FLS110 package should not be used to define the Z-axis stop** as this will create forces on the package during assembly that risk damaging it and negatively impacting the sensor performance.

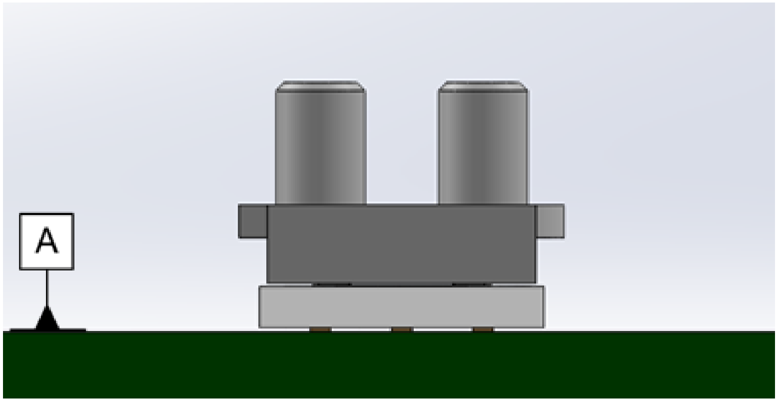

Figure 3: Locate the FLS110 in the Z-axis using the PCB surface (A)

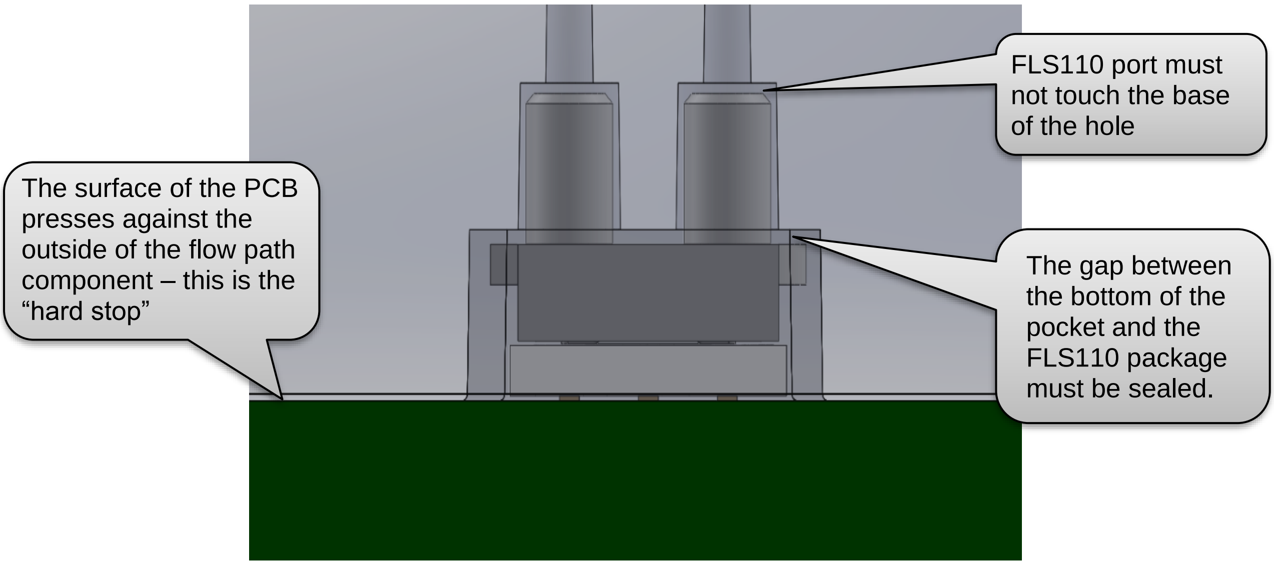

Figure 4: Cross-section through the pocket with the FLS110 inserted

By using the surface of the PCB (marked A in Figure 3) **variations in PCB thickness are eliminated**. The thickness of the solder paste layer underneath the FLS110 is still important, but this is usually small and well controlled.

Variations in clearance between the FLS110 and the internal features of the pocket should be minimised as far as possible in the design. Sealing the remaining gap between surfaces of the FLS110 and the fluid path wall is covered in section 4.

3 Strain relief

Designing the sensor mounting with appropriate strain relief prevents the sensor from being exposed to large forces that might develop due to the moving or flexing of parts within the design during normal use or foreseeable misuse. Excessive force on the sensor may lead to damaging the sensor. However, less force may result in compromising the seal between the sensor and the main fluidic path or altering the inlet conditions into the sensor. This may result in reduced accuracy or repeatability of readings over time.

Figure 5 shows the FLS110 Evaluation Kit sensor module: a small, rigid PCB with the FLS110 on one side and a microcontroller and connector on the other. Such a PCB is ideal for providing strain relief for the FLS110 at the interface to the fluid path.

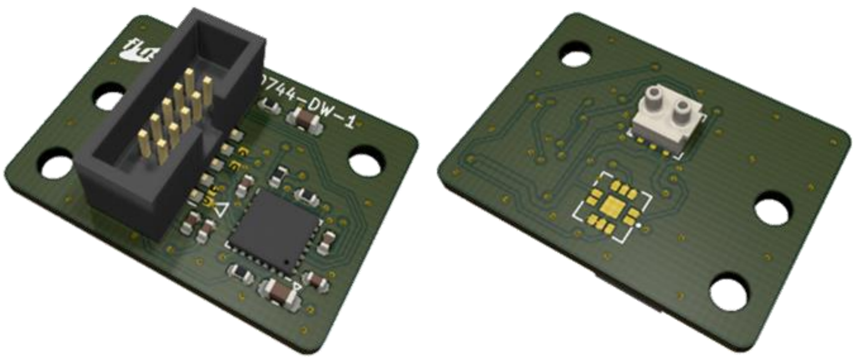

Figure 5: FLS110 sensor module

Figure 6 shows the sensor module installed into a fluidic test fixture.

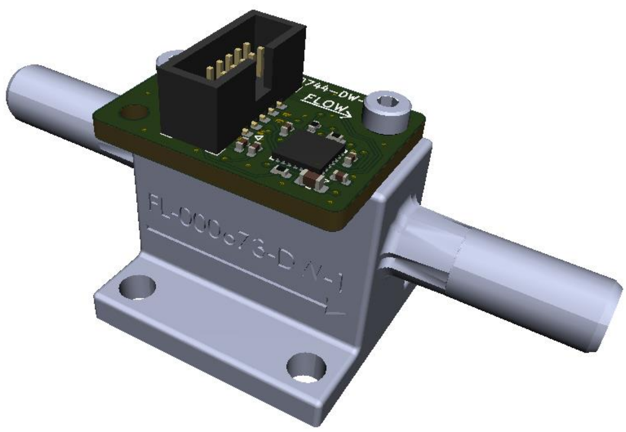

Figure 6: The FLS110 sensor module installed into a fluidic test fixture

Screws hold the PCB securely to the fixture and resist mechanical forces which could otherwise move the module relative to the fixture. This ensures that the FLS110 is not exposed to forces which might cause damage.

If screws are not appropriate for your design, heat stakes may be an alternative. Very high bond (VHB) adhesive tape and plastic clips may also be suitable for some applications where stresses will be low. However, the effect on the z-axis tolerance stack must be carefully considered to ensure reliable compression of a sealing element. **Liquid adhesives are not recommended due to the risk of adhesive (or adhesive vapours) contaminating the FLS110 and affecting performance.**

4 Sealing the FLS110 fluidic interface

4.1 Why is an airtight seal to the FLS110 required?

Whether the FLS110 is used to measure system flow through a bypass fixture or differential pressure, it operates by measuring a small mass flow through the device, from the inlet port to the outlet. Some of the air escaping from the flow path could lead to a large discrepancy in the reported flow rate or differential pressure. It is therefore important to achieve a good seal between the FLS110 and the flow path component of your product.

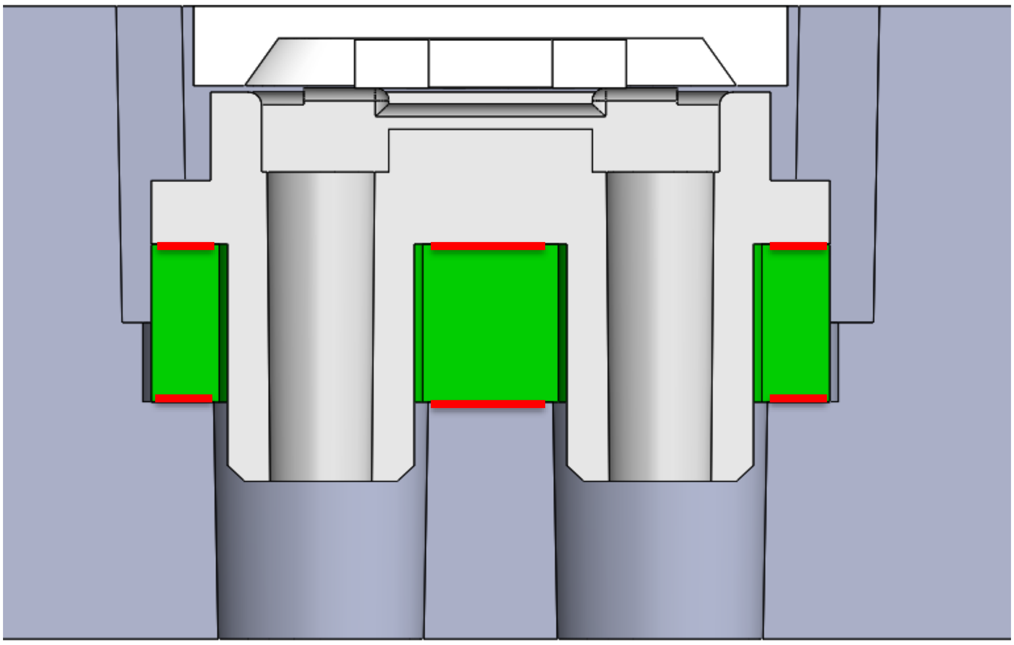

Figure 7: The FLS110, with gasket, installed in the system flow path with sealing surfaces highlighted in red

Figure 7 shows the design intent. The seal is made on the surfaces of the FLS110 and the socket that are normal to the compression of the gasket. **It is important to seal between the ports** as well as to ambient as air leaking between the ports will reduce the performance of the FLS110.

4.2 Rubber Gasket

Using a rubber gasket is a widely used approach in sealing a flow sensor to the body of the fluidic fixture. For typical operational temperature and pressure ranges, a wide variety of different elastomeric materials may be suitable such as NBR, Silicone, EPDM, Butyl rubber and SBR. Thermoplastic elastomers may also be suitable sealing materials. Variants of these material types are available for medical grade devices or for demanding conditions in your application.

The rubber gasket may be a separate part or integrated into the fixture through the use of a two-shot moulding process. Whether a two-shot moulding process provides a cost advantage over a separate sealing part will depend on manufacturing volume and assembly flow.

Two examples of a gasket are shown in green in Figure 8, below. The thickness of the rubber is recommended to be about 1mm. If the gasket is too thin it may be difficult to ensure the correct compression due to the tolerance stack. If the gasket is too thick it may be difficult to locate the FLS110 ports into the flow paths in the socket. The Gasket needs to be designed to seal around and between the ports. This is to ensure that the air flow cannot leak out of the fixture nor shortcut between the inlet and outlet of the flow sensor. Both would result in error-prone readings of the sensor.

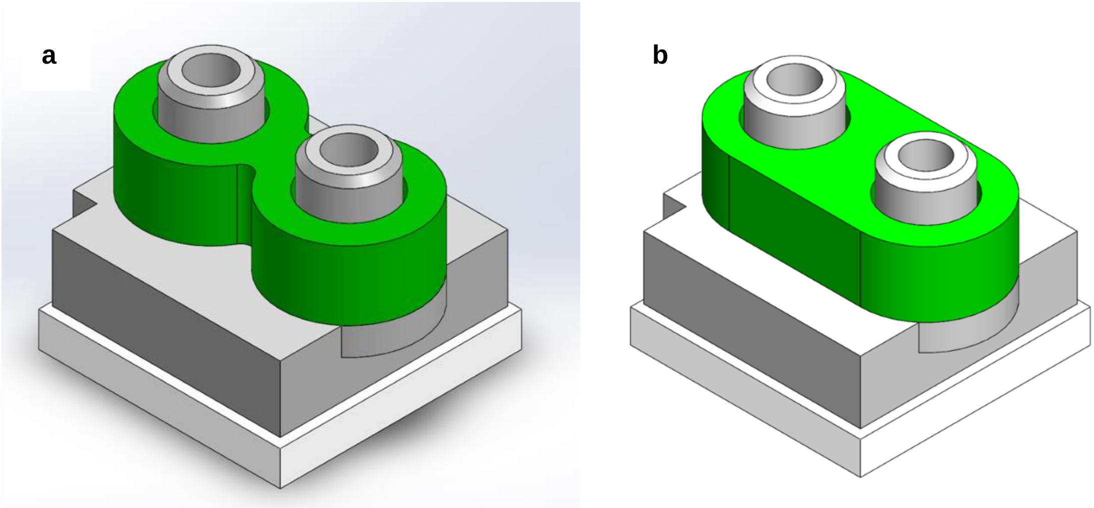

Figure 8: In green two different designs of gasket (in green) that could be used with FLS110.

The hourglass shape in a is better suited to rubber gaskets, whereas the easier shape of b is suitable for foam rubber gaskets.

The target compression of the gasket should be in the region of 15% and a low Shore hardness rubber is preferred to minimise compressive stresses on the FLS110 package upon insertion.

The small size of the FLS110 and the relatively small compression range of a solid rubber gasket will require tight control of the dimensions of the socket in the fluidic fixture to get a reliable seal. However, a well-designed solid rubber gasket made of an appropriate material can provide an airtight seal over a wide range of temperature and pressure conditions.

The gasket will need to be permanently compressed; this can be achieved by using screws of other fixings on the PCB located close to the FLS110. For fixings further away from the FLS110 the flex in the PCB will need to be considered as this may reduce compression of the gasket. Screw fixings are recommended to ensure the PCB is held firmly against the fluidic fixture. Plastic clips or heat stakes may introduce play in the assembly which may affect gasket compression.

4.3 Foam Rubber Gasket

For applications where the pressure differentials between the ports are small and the flow pressure is close to ambient a foam rubber gasket may provide an attractive alternative to solid rubber. Foam rubber gaskets can be used with much higher compression ratios than solid rubber, often in excess of 50%. This may allow a foam gasket to cope with larger tolerances in the clearance between the FLS110 package and the sealing surface of the fluidic fixture socket. If plastic clips or heat stakes are used to hold the PCB, a foam gasket may be better able to manage the small amount of slope they can introduce in the Z-axis.

A closed cell foam should be specified for airtightness and materials with good compression set and low stress relaxation are preferred. A similar design approach to a solid rubber gasket can be used choosing sealing surfaces normal to the axis of compression and constraining the outer edges of the foam gasket. Unlike a solid rubber gasket, a foam gasket will not conserve volume when it is compressed and therefore need not have the hourglass cut-out recommended for a solid rubber gasket. An example is shown in Figure 8.b.

Small foam gaskets can be difficult to accurately die cut. This can be alleviated by including a PET reinforcement film in the centre of the foam gasket. This technology is now common in foam tapes from companies such as TESA to improve die cuttability.

4.4 Die cut PSA tape

In some applications it may be desirable to adhere a gasket part to either the FLS110 or the socket prior to the insertion operation. In this case a die cut pressure sensitive adhesive (PSA) tape may be a good solution. A wide variety of different tape constructions are available including solid rubbers and foam rubbers with and without a reinforcement film layer. As before a closed cell foam is recommended for airtightness.

We recommend using a single sided tape and applying it firmly to either the FLS110 package or the sealing surface of the socket in the fluidic fixture before inserting the FLS110 and securing the strain relief. Double sided adhesive tape may be more likely to snag and be displaced during insertion. Double sided tape may be used for strain relief and mechanical fixing of the PCB. In this case using a slightly thicker tape for the sealing gasket and thinner tape for the mechanical attachment should help ensure the sealing gasket remains sufficiently compressed.

Replacing traditional mechanical fixings with PSA tape is becoming common amongst high-volume electronic device manufacturers.

4.5 Liquid sealants and adhesives

Cyanoacrylate adhesives are not recommended due to the risk of cyanoacrylate vapours contaminating the FLS110 and damaging performance.

The use of liquid sealants or adhesives to seal the FLS110 to the fluidic fixture is a possible solution. If liquid adhesives are to be used the following challenges must be addressed for best performance:

1. Ensuring the ports of the FLS110 are not occluded by adhesive

Unlike an open package MEMS pressure sensor **even partial occlusion** of the ports of the FLS110 will have a significant impact on the sensor performance.

2. Ensuring a complete seal between the fluidic fixture and the FLS110 and a complete seal between the two ports
3. Ensuring the bond is flexible enough to tolerate small relative movements of the FLS110 due to flexion of the fluidic fixture and expansion/contraction due to changes in temperature or pressure. Failure after many cycles due to fatigue of the bond should be considered.

Viscous and permanently flexible adhesives that can seal the sensor with a thicker bond line will be the most robust to small movements of the sensor relative to the flow path. However, it may be more difficult to ensure that they form an airtight seal around both ports.

Less viscous adhesives will require a thinner bond line. Even if these adhesives are flexible a very thin bond line will be less tolerant of relative motion between the FLS110 package and the flow path. A less viscous adhesive may be more capable of wicking into the fine gaps between the FLS110 and the flow path. This may assist with guaranteeing an airtight seal.

An adhesive bond between the FLS110 package and the flow path is likely to make the sensor difficult to remove without causing damage to the package. If rework or maintenance is likely a gasket may be preferable.

5 Comparison and summary

Table 1 gives a concise summary of the different sealing methods.

Sealing solution	Advantages	Disadvantages
Solid rubber gasket or two-shot moulded seal	Better for higher pressures and temperatures.	Careful control of tolerance stack is required, and assembly of the gasket may be problematic.
Foamed rubber gasket	More tolerant of variations in gasket compression due to part and assembly tolerances.	May not create as tight a seal as a solid rubber gasket particularly under higher pressures and temperatures.
PSA tape (single sided)	Solid or foamed rubber tapes available (see above advantages). Affixing to part or socket in advance may speed final assembly.	Similar to above depending on the type of tape used.
Adhesives	No additional part	Liquid adhesive at risk of blocking ports. Vapours may contaminate the sensor. May require additional process verification and validation to ensure a consistent seal throughout the life of the product. Cure time may impact volume production.

Table 1: Summary of the advantages of different methods of sealing the FLS110 flow path to the fluidic fixture or your device.