Guide to [Pressure] Sensor Selection

Sensor Solutions: A Series

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WHY CHOOSING THE RIGHT SENSOR MATTERS

Advances in medical devices are helping transition the healthcare industry from a subjective mindset to that of a quantitative mindset. Smarter medical devices are enabling physicians and healthcare workers to produce quantifiable data that lead to more supportive diagnosis and better data-driven treatments, thereby contributing to an overall improvement in patient quality of life. This transition is being largely enabled by advances in sensor technology.

With over 50 years of manufacturing knowledge and industry expertise, Millar is the pressure and pH sensor technology expert when customers need innovative, integrative solutions to take their medical device from concept to commercialization quickly, efficiently, and cost-effectively.

Our OEM partnership process is designed to uncover innovative ways to reduce risk, lower costs and reach patients faster – together. A key part in that OEM partnership is the selection of the sensor. One of the most frequently asked questions regarding sensor selection is: “Which sensor is the best?” Of course, there is no simple answer to this question. Each sensor has certain capabilities and limitations, so to choose the correct option, one must first consider the following factors.

WHAT IS A MEMS SENSOR?

Microelectromechanical systems (MEMS) integrate mechanical elements, sensors, actuators and electronics through the latest microfabrication technology. These high-performance, medically proven sensors can seamlessly integrate with a wide range of medical devices and life sciences technologies that are driving the next wave of lifesaving medical innovation.

A MEMS based piezoresistive sensor is one of the most effective ways to measure pressure in the body. This is a sensor with a piezoresistive diaphragm that is connected to a Wheatstone bridge circuit. MEMS sensors can be leveraged in medical devices by providing closed-loop feedback while enabling increased device responsiveness and improved therapy outcomes. This reduces facility costs while increasing the device’s value proposition. A pressure sensor can act as a switch, communicating to a control unit when a preset pressure threshold is achieved in order to cease, continue, or change a treatment method.

Additionally, MEMS sensors have several advantages that make them attractive for use in medical applications. Their small size allow integration into complex medical devices where real estate for additional sensors is at a premium. MEMS devices are manufactured with materials such as silicon and glass; as well as precious metals like titanium, gold, and platinum; and organic materials like Parylene, which makes these devices biocompatible. MEMS pressure sensors have a long history in medical applications and have been used in non-invasive and envasive medical equipment for decades.

PRESSURE SENSORS

MEMS VS. FLUID FILLED VS. FIBER OPTIC

Effective integration of a pressure sensor in a medical device requires in-depth knowledge of sensor types, capabilities, validation, and manufacturing requirements. Each technology presents different attributes that are necessary to be understood for proper use.

Fiber-optic sensors shine laser light into an optical fiber. The end of the fiber is often equipped with a flexible membrane that flexes in relation to applied pressure and temperature. Changes in the membrane are sensed by shifts in wavelength of reflected light. This sensor requires a reasonably complex receiving electronics system that also has to correct for temperature effects. Integration of these sensors requires care such that the bending of the catheter does not add additional strain over the signal being measured. Fiber optic cables within the catheters are fragile and may be prone to cracking, increasing integration costs. This is a known problem, and most clinicians take adequate care to prevent such incidents.

Fluid-filled sensors use an external transducer coupled by a fluid-filled catheter that communicates the pressure from the source. Problems associated with fluid-filled lines include viscous damping resulting from the long catheter and extension tubing. Further, dynamic pressure changes such as those produced in normal cardiac operation cause measured signals to peak much higher than the actual pressure. This results from resonance within the tubing system. Using fluid-filled systems is an art, and success depends on how the sensor is set-up and used.

MEMS piezoresistive sensors measure a change in resistance across a thin silicon diaphragm that deflects with changes in pressure. This technology is widely used in industrial sensors and is well proven. The sensors are rugged and measure pressure only at the source. Over the years, Millar has perfected integration methods with these sensors to greatly reduce effects of drift resulting from manufacturing. Catheters built with sensor tips are robust and can navigate tortuous paths in the human vasculature. The interface electronics are fairly simple and can connect to commercially available monitors. Since pressure is measured only at the tip, this technology does not suffer from damping and resonance effects of fluid-filled lines.

	MEMS	Fiber Optics	Fluid-Filled
High frequency response	YES	YES	NO
Measures pressure at source	YES	YES	NO
Robust design	YES	NO	YES
Accuracy during movement or bend	YES	NO	NO
No overshoot, true signal	YES	YES	NO

PRESSURE SENSORS

PIEZORESISTIVE VS. CAPACITIVE SENSORS

MEMS **capacitive sensors** measure pressure as a function of capacitance between a flexible silicon diaphragm and another rigid silicon wafer. A benefit of capacitive sensors is that they do not have static current consumption and are an attractive option for battery operated applications. Capacitive sensors require careful integration. The signal conditioning electronics should be ideally co-located in the same package as the sensor to avoid parasitic capacitance from long wires.

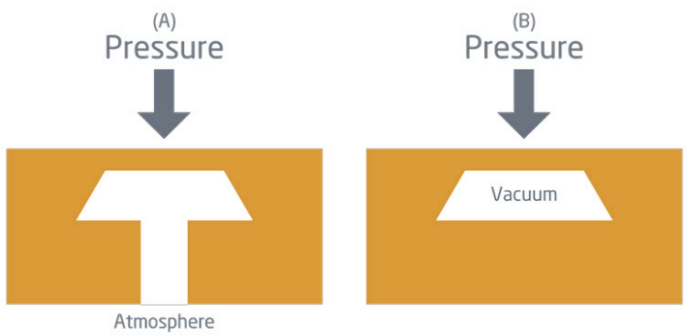
However, **piezoresistive sensors** are more widely available, and they are available in smaller sizes than capacitive sensors. Piezoresistive sensors are available in the half-bridge and full bridge configurations. Half-bridge sensors are ideally suited for catheter-based applications on account of their small dimensions.

ABSOLUTE VS. VENTED

There are two types of MEMS sensors that Millar offers: Vented (also commonly referred to as gauge) and Absolute.

Vented (or gauge) sensors (A) are open on the back side of the diaphragm and constantly reference atmospheric pressure. Vented sensors therefore “self-correct” for changes in atmospheric pressure. Because vented sensors are “self-correcting”, the interfacing electronics and analysis tend to be simpler than what’s required for an absolute sensor. However, vented sensors require a continuous vent to atmospheric pressure, which can be a challenge in designs with limited space.

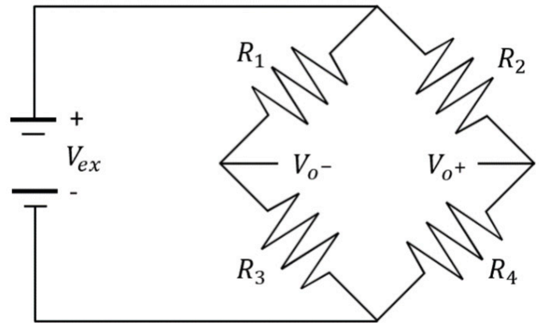
Absolute sensors (B) are sealed under the diaphragm and therefore provide a pressure reading relative to a constant baseline pressure. Because the back side of the diaphragm is always referencing a set pressure, readings from an absolute pressure sensor must be corrected for any changes in the atmospheric pressure. Absolute sensors therefore require a second barometric pressure sensor in the system, before they’re able to provide pressure measurements. The barometric pressure sensor can often either be placed in the device itself or in the interfacing hardware.



PRESSURE SENSORS

FULL BRIDGE VS. HALF BRIDGE

A Wheatsone bridge is a common electric circuit used to measure small changes in resistance. A Wheatstone bridge is composed of four different resistors, as shown in the schematic below.



Millar's sensors leverage either full-bridge or half-bridge circuit configurator. In a **full-bridge sensor,** all four resistors are contained on the sensor diaphragm. In a half-bridge sensor, only two of the four resistors are contained on the sensor diaphragm; the other two resistors are completed in the circuit/hardware.

A full-bridge sensor will generally have a smaller temperature effect, because all four resistors are contained on the same surface (and therefore exposed to the same temperature). However, a **half-bridge sensor** will generally be smaller, due to the fact that it has less resistors contained on the sensor diaphragm (and therefore does not need as much surface area). Millar's half-bridge sensors utilize a proven temperature compensation network located in the connector to minimize the temperature offset inherent in all MEMS sensors. This network is compatible with all standard off the shelve bridge amplifiers.

DIGITAL VS. ANALOG

Signal conditioning for the sensors is required to present an interface that removes process variations, and reduces temperature dependence and non-linearity. Signal conditioning can be either analog or digital:

Analog signal conditioning uses a passive network of resistors and potentiometers that are set during the calibration process. The resistor network presents a 4-pin signal interface that can then be sampled by an ADC in the user's system hardware. This provides a simple and cost-effective option if the end user has hardware available for signal conditioning.

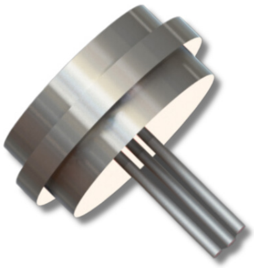
An increasingly attractive option is **digital** signal conditioning. The sensor is interfaced to signal conditioner components, which contain the calibration coefficients and can provide a digital read-out. Data is available in several output formats: I2C, SPI, one-wire, and as a pulsewidth modulated signal. This can be directly read by the microcontroller in the user's hardware. This provides a plug and play capability to the end user without the need for dedicated signal conditioning hardware. Digital signal conditioning is ideal for wireless and battery operated applications.

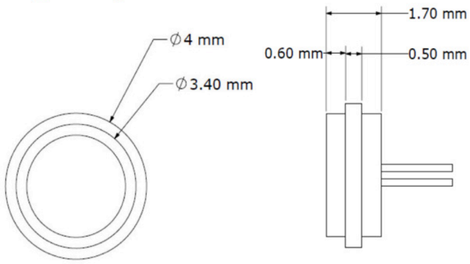
PRESSURE SENSORS

ACUTE VS. CHRONIC

Millar's **acute** catheter-based offerings typically span in durations from <24 hours to 29 days. The range of applications for acute sensors is broad and includes intracranial pressures, a variety of cardiovascular pressures, airway pressures, and compartment pressures.

Millar's TiSense module stands out as an ideal solution for long-term pressure measurements. It is made up of a MEMS piezo-resistive sensor integrated into a **chronic** implantable sensor module. Crafted from titanium, the module is encapsulated and hermetically sealed, allowing for implantation periods exceeding 5 years. TiSense is designed for long-term, implantable devices that support chronic conditions such as heart failure, hydrocephalus, and intraocular pressures.





SENSOR SIZE

In the evolving landscape of medical devices, there is a growing emphasis on enhancing functionality through miniaturization and additional capabilities, including pressure & pH sensing components. Millar uses the French scale to denote our catheter casing requirements for sensor integration, where each French unit corresponds to a specific diameter.

One French (1Fr) is equivalent to 0.33mm (or 330µm) in diameter, while Three French (3Fr) is equivalent to 1mm (or 1000µm) in diameter. The most challenging applications require integrating a sensor into a 1F catheter body or inner lumen. Millar's sensors are commonly integrated into various medical devices, including catheters, probes, and monitoring devices.

SENSOR FOUNDRY

Tailoring solutions for small to medium-sized device manufacturers, our pure play sensor mircofoundry is the heart of Millar's sensor development process. We offer both off-the-shelf and custom solutions to meet our customers' unique needs, ensuring the fastest path from design to full device integration. Millar has strategic partnerships with leading MEMS sensor foundries for larger-scale projects. When you're ready to scale up, we'll be there to connect you with the right resources. Learn how our collaborations can drive growth for your sensor innovations.

Whether you require low-volume, high-precision sensor manufacturing or rapid prototyping services, Millar's MEMS sensor foundry is your partner in sensor innovation. Our sensor portfolio includes Wheatstone bridge full and half-bridge pressure sensors, ISFET pH sensors, electrical conductivity sensors and more. Each step of the production process, from lithography to chemical vapor deposition, diffusion, and annealing, is carefully performed in-house. This meticulous approach ensures optimal sensor performance and reliability, backed by our state-of-the-art facilities including a testing factory, a fully equipped tooling shop, an electronic and PCB circuit design facility, and a comprehensive sensor and product assembly facility.

PRESSURE SENSOR SPECIFICATIONS

Half-Bridge

Parameter	Value
Sensitivity	5 µV/V/mmHg
Size Range	Length 900µm-1150µm Width 330µm-725µm
Pressure Range	-50 to 300 mmHg
Accuracy & Linearity	+/- 1% error over -50 to 150 mmHg applied pressure
Temperature Error	<3.5% (15-40) deg C.
Drift	Average = 0.89 ± 0.44 mmHg over 7 days Max < 2.5 mmHg over 7 days Max < 5 mmHg over 30 days
Bridge Resistance	3.4 KΩ +/- 20%
Resolution	Analog output (digital integration also available)

Full-Bridge

Parameter	Value
Sensitivity	8-15 µV/V/mmHg
Size Range	Length 1600µm-3000µm Width 800µm-1000µm
Pressure Range	-300 to +1000 mmHg
Accuracy & Linearity	< 1% error over -50 to 200 mmHg applied pressure
Temperature Error	< 1% (15-40) deg C.
Drift	Average = 0.2 ± 0.1 mmHg over 3 hours Max < 0.3 mmHg over 3 hours
Bridge Resistance	3.9K to 5.1K
Resolution	Analog output

Explore our Guide to pH Sensor Selection for more detailed pH sensor specifications and an in-depth look at our ISFET Technology. Ready to experience Millar's MEMS Pressure sensors firsthand? Our fully customizable MEMS Developer Kit allows you to test integration with your existing medical devices and technology. Discover the possibilities and learn more here.

IN CONCLUSION

Millar has over 50 years of MEMS integration and catheter manufacturing expertise and our tested process is guaranteed to improve yields and relieve the challenges of integration, resulting in reduced costs and faster time to market. Proper integration of the sensor is critical to the performance of the sensor and ultimately, the device.

Therefore, many device companies are choosing to leverage the experience of sensor integrators like Millar. The integration of a MEMS pressure or pH sensor is an intricate and detailed process, but through feasibility studies, fit for purpose solutions and production of prototypes, Millar is quick to solve integration challenges to reduce the costs and timeline from concept to market. To learn more, or to speak with a member of our team, please don't hesitate to contact us at insights@millar.com.

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