

THE ECONOMICS OF ACCURACY IN LOW-COST, HIGH-VOLUME SENSING APPLICATIONS

A Honeywell White Paper



Abstract



Various research firms forecast the market for portable medical devices to be somewhere around the \$20 billion range within the next several years. Part of the increased demand is due to an aging population with more chronic conditions. One firm, for example, predicts the homecare medical equipment market [could be worth nearly \\$26 billion by 2022](#) – part of that is driven by mobile health monitoring devices, personal oxygen concentrators and stationary equipment. But home healthcare is only part of the story. For instance, transporting patients on planes, helicopters and other areas where space is at a premium requires devices with smaller footprints. Simply put, medical devices in general are smaller, and more practical, today.

By the same token, smaller devices need to provide adequate levels of care to ensure patient safety and comfort. Thus, functionality cannot be sacrificed for space. This presents a challenge: smaller devices are becoming less expensive to manufacture, but high functionality can be expensive. Advanced basic pressure sensors represent a potential solution, provided their accuracy levels are appropriate.

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Introduction

Low-cost advanced basic pressure sensors have become a valuable commodity, in particular with engineers who need to design and create low-cost, high-volume assemblies in sectors such as industrial manufacturing and healthcare. This, of course, is due to the fact that original equipment manufacturers in these vertical markets are experiencing a greater demand for products in these applications. One of the biggest factors influencing this demand is mobility.

In the healthcare market, for instance, the greater emphasis on designing technology that is less intrusive on people's lives has led to a demand for smaller devices. This is seen with devices such as oxygen concentrators, CPAP machines, and others. Additionally, as tasks like medical procedures need to be performed in smaller spaces (in some cases, in remote locations), space is at a premium. This means even equipment that traditionally has been large (e.g. ventilators) has also become smaller.

On the surface, the math is simple: there's a greater demand for these types of smaller, more compact, devices. Naturally, there's a greater demand for the smaller components that go inside them. As the devices must become smaller, though, there is also an expectation of greater functionality. Take, for example, the area of pneumatic controls, where there is a greater emphasis on smaller devices that also provide highly accurate readings.

Thus, the increasingly sophisticated nature of these devices also means there's a greater demand for better functionality of the components (i.e. sensors) themselves. Of course, this becomes problematic because higher degrees of accuracy are usually associated with higher price tags, which isn't very practical when dealing with low-cost, high-volume applications. This isn't the case in higher-cost applications, when engineers can more-easily justify the investment with the need for more accurate devices due to their lower error budget requirement.

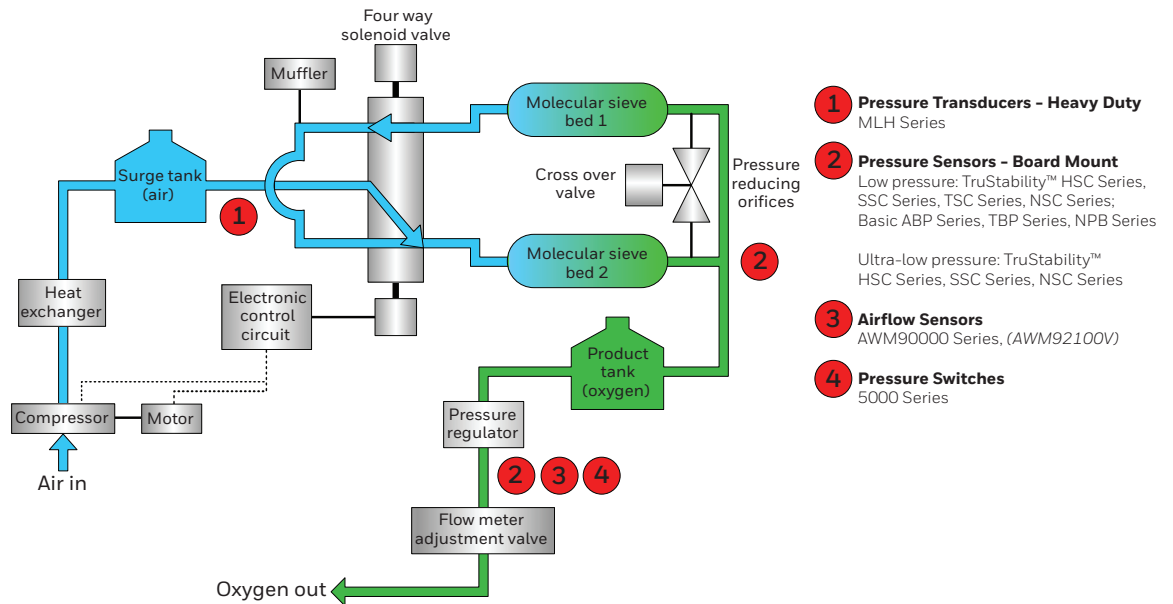
A ventilator, for instance, can cost tens of thousands of dollars to design and build; in this particular case, when a more-expensive (~\$15) sensor ends up being less than 1% of the total cost, the investment is completely justified. On the other hand, when designing a blood pressure monitoring application that only costs \$40 - \$120 for design and build, spending an extra \$15 for 1.5%FSS of Total Error Band improvement does not make financial sense.

Staying within budget is a priority. So the question becomes: how does one best evaluate the accuracy capabilities of low-cost sensors in a way that makes practical and economic sense?

Deriving value from these types of applications requires designers to view these components not purely as commodities, but as critical technology enablers that give engineers a competitive advantage.

The Argument for (Low-Cost) Accuracy

Figure 1. Potential Honeywell Products Used in an Oxygen Concentrator Application



While having the accuracy of a more-expensive sensor may not make financial sense for a low-cost, high-volume application, the accuracy of a less-expensive technology should not be disregarded just because it's not a premium solution. This is especially important as factors such as lower power consumption, repeatability and reliability have increased in importance for design engineers looking to maintain tighter error budgets and improve system specifications. Additionally, lower power consumption has become a stronger selling point for end-user customers. Thus, accuracy can become a differentiating factor for a device, regardless if it's "low cost."

Taking the example of an oxygen concentrator, low and ultra-low pressure silicon sensors may be used to detect when a patient begins to inhale so that oxygen can then be delivered efficiently and effectively, minimizing oxygen waste when the patient isn't inhaling. This allows the oxygen concentrator to be smaller and to operate more efficiently. Smaller equipment size also means lower power consumption, as well as greater portability.

Another key factor that supports the argument for not skimping on accuracy in low-cost applications is the need to retain the benefits of easier-to-install components such as compensated or amplified compensated sensors. Less-accurate sensing technology could very well negate some of the benefits achieved by using plug-and-play technology, such as the ability to help relax specifications in other parts of the system. This benefit may be of greater value particularly for engineers struggling to meet design requirements.

For example, being able to more-accurately measure pressure inside an oxygen concentrator may negate the need to regulate down to the minute details, or overcompensate elsewhere in the system.

The desire for low-cost "plug-and-play" devices in part explains the growing popularity of amplified compensated vs. uncompensated sensors. Amplified compensated sensors can typically be used without the need for additional modifications, and can provide part-to-part interchangeability, calibration and temperature compensation. A non-amplified compensated sensor may require the use of amplification circuitry, assuming that an ASIC (application-specific integrated circuit) with a mV input ADC (analog digital converter) is not being used. In contrast, uncompensated sensors provide raw sensor output and usually require some form of compensation, as shown in Figures 2 and 3, in order to be used in many applications.

Figure 2. Two typical circuits that may be used for temperature compensation.

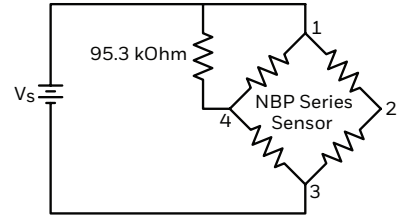
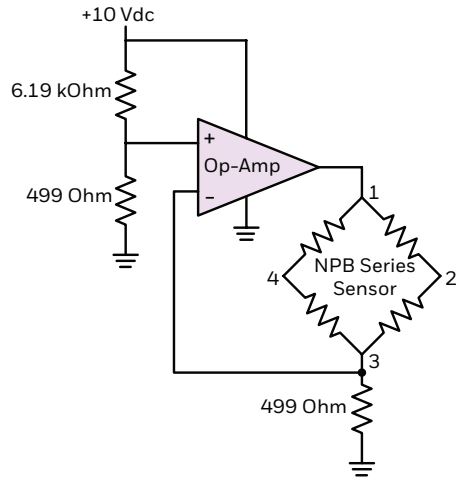
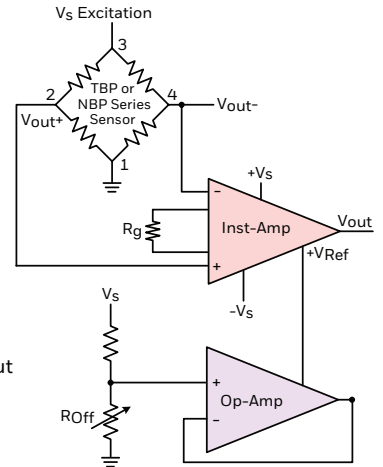
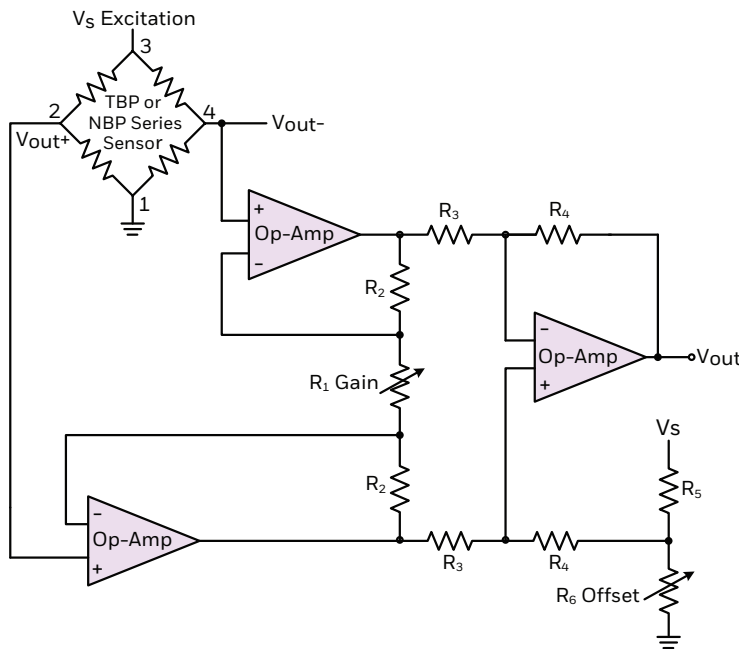


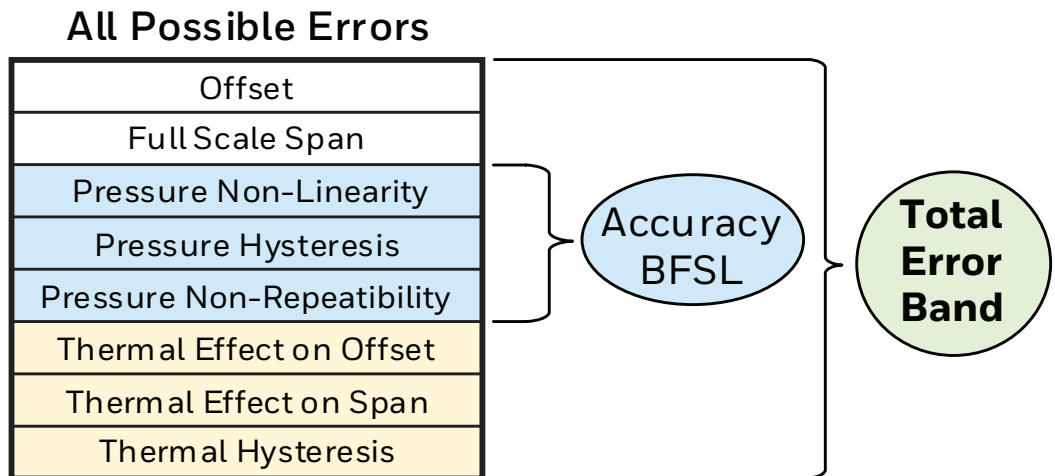
Figure 3. Two typical circuits that may be used for output amplification.



Using plug-and-play solutions such as a fully amplified, compensated sensor eliminates the need for the additional circuitry and design time to develop, and therefore provides greater value. Again, though, a plug-and-play solution which doesn't provide accurate data defeats the overall purpose; poor performance could potentially negate any savings gained through the easier installation.

An uncompensated sensor with a Total Error Band (TEB) of greater than 30%FSS may cost \$9 and a compensated sensor with a TEB of about 10%FSS may cost \$10, whereas a fully amplified plug-and-play sensor with a TEB of 1.5%FSS may cost \$13. With these parameters, it only makes sense to implement additional circuitry to improve the accuracy of the less-expensive sensors if the component costs, not to mention design and calibration time involved, is less than \$4. In doing the upfront analysis, many engineers realize the plug-and-play device actually provides the best price/performance value.

Figure 4. Total Error Band (TEB) is the maximum deviation in output from the ideal transfer function over the entire compensated temperature and pressure range. TEB includes all possible errors as shown.



Examining a Real-Life Application: Oxygen Concentrators

Figure 5. Oxygen Concentrator.



Portable oxygen concentrators have steadily decreased in size over the last several decades, making them easier to use in transport on airplanes, for instance. Smaller sensing solutions such as the amplified basic pressure sensor have enabled OEMs to further shrink the physical footprints of these devices. Taking things a step further, higher degrees of sensing accuracy can help provide as high a quality level of care and comfort typically found with larger, “state-of-the-art” systems found in hospitals.

First, consider the basic function of an oxygen concentrator. The device reduces the amount of nitrogen in the air, thereby increasing the oxygen level delivered to the patient. Oxygen concentrators are used with patients, such as those with lung disease, who have difficulty absorbing oxygen into the blood stream.

An amplified basic pressure sensor may be used to monitor the pressure internally in the sieve bed so that it can generate the required oxygen levels for the patient. Air is comprised mostly of nitrogen (78%) and approximately 21% oxygen. By removing the nitrogen from the air, the concentration of oxygen is significantly increased. There are two sieve beds with zeolite materials that are pressurized with air. By pressurizing the air, the zeolite sieve bed absorbs the nitrogen.

Controlling the pressure in the sieve bed helps control the concentration of oxygen in the air for the patient. The sensor may also be used to detect when the patient begins to inhale so that oxygen can then be delivered efficiently and effectively. The use of a pressure sensor to monitor when the patient begins to inhale helps to minimize wasting oxygen when the patient isn’t inhaling. This allows the oxygen concentrator to be smaller and to operate more efficiently. Smaller equipment size also means lower power consumption, as well as greater portability.

All of these factors provide advantages device makers can point to in order to distinguish competing products that use less-accurate sensors.

Other Real-Life Applications

Figure 6. Sleep Apnea Mask.



Amplified advanced basic pressure sensors (such as Honeywell's Basic Amplified ABP Series) are intended for use with non-corrosive, non-ionic gases, such as air and other dry gases. The following options extend the performance of these sensors to non-corrosive liquids:

- Dry gases option: The input port is limited to non-corrosive, non-ionic media (e.g., dry air, gases) and should not be exposed to condensation. The gases are limited to media compatible with high temperature polyamide, silicone, alumina ceramic, silicon, gold, and glass.
- Liquid media option: Uses the same construction materials and is protected from noncorrosive fluids on both Ports 1 and 2 by a silicone-based gel coating, which protects exposed electronics on Port 1. Because Port P2 is naturally protected from non-corrosive liquids, this option is a wet/wet sensor, allowing liquid usage on both ports. Compatible media are condensation, water and saline.

The following examples represent some of the healthcare applications these types of sensors can be used to design:

- Blood analyzers
- Blood pressure monitoring
- Hospital beds
- Massage machines
- Sleep apnea equipment
- Urine analyzers
- Ventilators/portable ventilators
- Wound therapy

Conclusion

While portable medical devices are nothing new, they continue to get smaller and easier for patients who prefer to receive higher-quality healthcare in the comfort of their own homes. They're also more practical for medical professionals who need to provide care in challenging locations. Neither the professionals nor the patients, however, can afford to sacrifice functionality for the benefits of size and portability. While these smaller, low-cost devices can function adequately with lower-cost sensors, the accuracy of those lower-cost sensors is not something to take lightly. If approached thoughtfully, placing a higher priority on sensor accuracy can help equipment manufacturers truly differentiate their products' value as the market for this technology grows in the future.

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