Superior SENSOR TECHNOLOGY

The Importance of Pressure Sensors in PAP Machines

Q4 2021

www.superiorsensors.com info@superiorsensors.com

Table of Contents

Sleep Apnea

Sleep apnea is a serious sleep disorder that occurs when a person's breathing is interrupted during sleep. Untreated, those with sleep apnea stop breathing repeatedly during their sleep. This can happen hundreds of times over a 6 to 8 hours sleep cycle. When a person stops breathing, the brain – and the rest of the body – may not be getting enough oxygen.

Potentially life threatening, sleep apnea is far more common than previously thought. It happens in both genders and all age groups. It is estimated that about 25% of men and nearly 10% of women suffer from sleep apnea. It can affect people of all ages, including infants, but it more common in those over 40 and overweight.

Per the Cleveland Clinic, there are two types of sleep apnea: obstructive and central.

- **Obstructive sleep apnea** is the more common and occurs as repetitive episodes of complete or partial upper airway blockage during sleep. During an apneic episode, the diaphragm and chest muscles work harder as the pressure increases to open the airway. Breathing usually resumes with a loud gasp or body jerk. These episodes can interfere with sound sleep, reduce the flow of oxygen to vital organs, and cause heart rhythm irregularities.
- In **central sleep apnea**, the airway is not blocked but the brain fails to signal the muscles to breathe due to instability in the respiratory control center. Central apnea is related to the function of the central nervous system.

If it's not treated, sleep apnea can cause several health problems, including hypertension (high blood pressure), stroke, cardiomyopathy (enlargement of the muscle tissue of the heart), heart failure, diabetes and heart attacks. Untreated sleep apnea can also be responsible for job impairment, work-related accidents and motor vehicle crashes, as well as underachievement in school in children and adolescents.

Most Common Devices to Treat Sleep Apnea

Positive Airway Pressure therapy, or PAP therapy, is the most common and recommended treatment for obstructive sleep apnea. With PAP therapy, patients wear a mask over their nose and/or mouth and an air blower gently forces air through the mask. The air pressure is adjusted so that it is just enough to prevent the upper airway tissues from collapsing during sleep. PAP therapy prevents airway closure while in use, but apnea episodes can return if PAP is stopped or if it is used improperly. Properly used, PAP helps patients breathe and maintain good blood oxygen levels throughout the night.

There are three main types of positive airway pressure devices depending on specific needs of the patient:

1. **CPAP (Continuous Positive Airway Pressure)**. CPAP is the most common type of machine. This device is programmed to produce pressurized air at one steady air pressure level. To change the air pressure, you have to reset the device's settings. If the patient needs more or less pressure during the night, the CPAP is not able to adjust.

2. **BiPAP (Bi-Level Positive Airway Pressure)**. BiPAP machines have two pressure settings, one pressure for inhaling and a lower pressure for exhaling. It's used for individuals who can't tolerate CPAP machines or have elevated carbon dioxide levels in their blood. BiPAP devices can also come with a backup respiratory rate for patients who have central sleep apnea. The backup respiratory rate ensures the person breathes, as the main problem with central sleep apnea is initiating breath. BiPAP is also helpful for other conditions affecting the lungs, such as COPD.
3. **APAP (Automatic Positive Airway Pressure)**. APAP machines check a patient's breathing throughout the night. They automatically adjust the air pressure to compensate for changes in sleep position or the effects of medications that may have changed breathing patterns. Unlike CPAP machines, APAP machines can automatically choose the right pressure setting based on a patient's breathing needs. This allows for much greater flexibility.

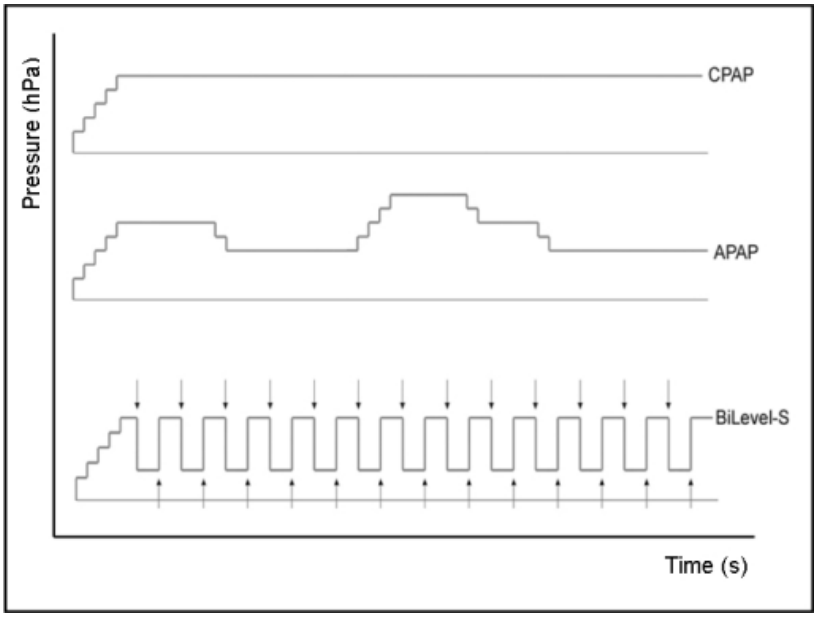

Figure 1 – Example of pressure patterns of CPAP vs. APAP vs. BiPAP
(source: NIH)

The Role of Pressure Sensors in PAP Machines

PAP machines include several types of sensors to monitor and/or regulate different functions, including airflow, air pressure, temperature and humidity. While adjusting temperature and humidity is important for the patient experience, this document will focus on the two functions that are served by pressure sensors: airflow and air pressure.

As seen in the following use cases, the most effective pressure sensors have a very fast feedback loop (to tell the system to adjust the fan more quickly when a patient is inhaling/exhaling), are able to effectively block out noise from fans and motors (to reduce error rates), can support

multiple pressures without any degradation in performance (to support all patient requirements) and have a high-resolution to ensure a very strong signal-to-noise (SNR) ratio.

CPAP

With a CPAP machine the pressure is set to one fixed value that is constantly applied throughout the treatment. In this implementation, a gage pressure sensor is used to measure the air pressure that is being applied to the patient from the machine. In some implementations, a second gage sensor is used to monitor the air pressure coming back from the patient to ensure there is no leakage due to an improperly placed mask. An alternate solution to dual gage sensors is the addition of a differential pressure sensor for measuring flow, which also enables the CPAP device to be configureable for BiPAP and APAP modalities.

BiPAP

As BiPAP machines need to monitor both patient breathing inflows and outflows, they require two pressure sensors: a gage pressure sensor to control the patient's pressure and a differential pressure sensor for system flow measurement. Specifically, pressure sensors monitor the patient's breathing and send a signal to the machine to reduce the applied pressure when a patient exhales and then increase it again when the patient inhales. Adjusting the applied pressure when inhaling and exhaling results in the patient being much more comfortable, and no longer 'fighting' against the sleep apnea machine when exhaling.

APAP

Similar to BiPAP, APAP machines will adjust the applied patient pressure throughout the night. But unlike BiPAP that adjusts between two settings, APAP machines are not limited to only two pre-defined settings. APAP machines automatically adjust patient pressure according to the resistance present in the patient's breathing. While pressure sensors monitor the patient's breathing and send a signal to the machine, an APAP machine varies the applied pressure based on precise requirements coming from the patient. Typically, an APAP machine is prescribed when neither a CPAP or BiPAP machine get the desired results.

Superior Sensor's Technology Advantage

Having an extremely low noise floor, the NimbleSense™ architecture is ideal for the precise, low-pressure measurements that PAP equipment require to maximize their accuracy and performance. In addition, Superior Sensors has gone a step further with its CP Series by integrating the two pressure sensors (gage and differential) in one device. This highly integrated dual sensor solution eliminates the need of a second pressure sensor. Finally, several application-specific building blocks provide additional capabilities to further improve the sleep apnea solution. These include Multi-Range Technology™, an advanced multi-order filter and integrated closed loop control.

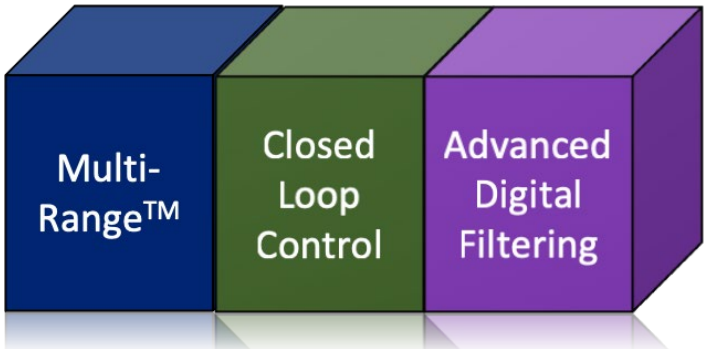

Figure 2 – NimbleSense Building Blocks that Benefit PAP Machines

Highly Integrated Dual Pressure Sensor Solution

Utilizing the same small package as our single sensor solutions, the CP Series is the industry's first fully integrated dual pressure sensor solution that also provides 64 possible configurations (see below). By combining the two sensors in one device, you simplify PAP product design, speed time to market, reduce PCB space requirements and lower overall system costs.

Industry's Lowest Noise Floor = Best Performance

The NimbleSense architecture was developed with the overarching goal to knock out every bit of noise before reaching the sensing system. This provides a much better SNR that competing solutions for both gage and differential pressure sensors. The net result is that both integrated sensors boast accuracy that is within 0.05% of the selected pressure range, total error band (TEB) within 0.15% of FSS and long-term stability within 0.15% of FSS per year.

Very Fast Response Time

As part of its superior performance, the CP Series has a very fast 2 millisecond update rate. This ensures that both sensors are providing timely feedback to the PAP machine, resulting in maximum patient comfort and machine efficiency.

Unprecedented Flexibility

With one product SKU, you can support up to 64 possible configurations with your PAP machine. This provides maximum flexibility and the ability to quickly manufacture derivative products to expand your product portfolio. Each of the two pressure sensors has 4 factory calibrated pressure ranges. In addition, there are four bandwidth filter options that can be selected. This level of flexibility is a first with pressure sensors for sleep apnea devices.

Optional Feature Integration

In addition to all the advantages described above, the CP Series offers some additional features that can be integrated into the sensor. An advanced multi-order filter can be implemented to further reduce any interference coming from fans or blowers. This eliminates noise before it can become an error signal. In addition, an integrated closed loop control can be implemented to

significantly reduce loop delays by controlling the fan/blower. Integrating these optional features will further simplify product design and improve system performance.

Conclusion

Potentially life threatening, sleep apnea is a serious disorder that affects hundreds of millions of people. PAP therapy is the most common and recommended treatment for sleep apnea, and PAP machines rely on pressure sensors to monitor both the airflow of the system and the patient's breathing.

Superior's CP Series of highly integrated sensors combines the two pressure sensors in one device to simply product design and reduce system cost. The company's NimbleSense architecture provides superior performance, faster response times and maximum flexibility with 64 possible configurations from one SKU. For more detailed information about our sleep apnea solution, please visit our product page or contact us.

Superior™ SENSOR TECHNOLOGY

www.superiorsensors.com info@superiorsensors.com