Sensors and Flexible Heaters in Sleep Apnea Machine Applications

BACKGROUND

Sleep apnea is the repeated cessation of breathing during sleep, sometimes hundreds of times during the night and often for a minute or longer. If left untreated, sleep apnea can cause high blood pressure, cardiovascular disease, memory loss, and weight problems. Recent medical studies indicate that long-term sleep apnea may also increase the risk of dying of cancer. The resulting lack of restful sleep may also be responsible for job impairment and motor vehicle accidents.

A main treatment option is the use of a Positive Airway Pressure (PAP) machine. (See Figure 1.) The patient wears a mask that uses pressure to send air flowing through the nasal passages so they don't collapse and cause breathing to cease. There are three main categories of PAPs (in order of complexity/cost):

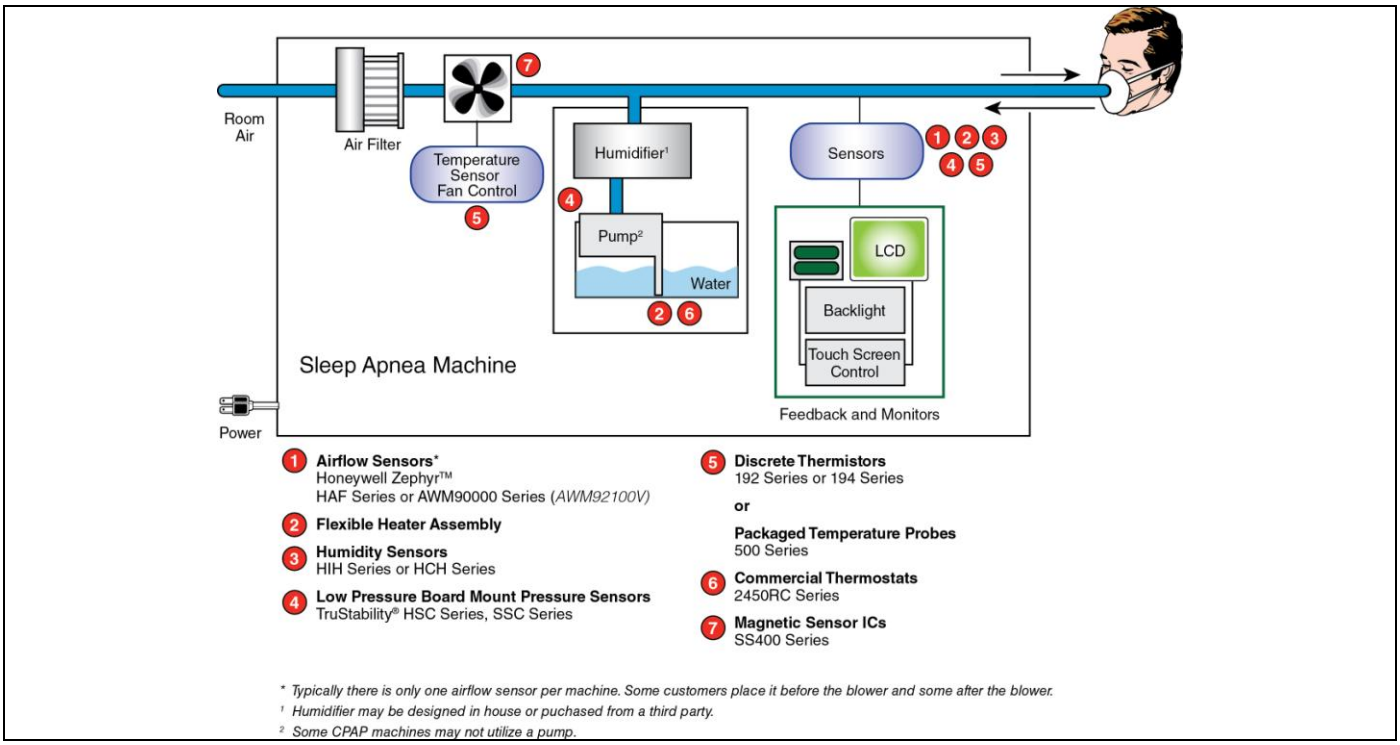
1. **CPAP** (Continuous Positive Airway Pressure) provides a constant pressure to the patient. This positive pressure keeps the throat from collapsing during sleep and allows the patient to breathe freely without worry of episodes of non-breathing.
2. **Auto-PAP** (Automatic Positive Airway Pressure) measures the resistance in a patient's breathing. The amount of continuous pressure delivered to the patient is then automatically tuned to the minimum required to maintain an unobstructed airway on a breath-by-breath basis.
3. **Bilevel-PAP** (Bilevel Positive Airway Pressure) provides two levels of pressure: IPAP (Inspiratory Positive Airway Pressure) and a lower EPAP (Expiratory Positive Airway Pressure).

Figure 1. Sleep Apnea Machine

SOLUTIONS

Honeywell manufactures many sensors and flexible heaters that may be used in sleep apnea machines. They are designed to help control airflow, pressure, humidity and temperature, and to provide output for smooth motor control. (See Figure 2.)

Figure 2. Potential Honeywell Products used in Sleep Apnea Machines



Airflow Sensors

These products monitor the patient's breathing and send an output that reduces the flow of the machine's internal blower fan when the patient starts to exhale. The resulting lowered resistance prevents the patient from feeling as though he is "fighting" against the machine when breathing, reducing discomfort.

Machines that use airflow sensors to detect the breathing cycle are more comfortable for the patient and are more likely to be used regularly than equipment without this feature. Some insurance companies and doctors often prefer this equipment due to greater patient compliance. These sensors are used in Auto-PAP and Bilevel-PAP machines. (See Table 1.)

Table 1. Airflow Sensors

Honeywell Zephyr™ Airflow Sensors: HAF Series (★ = *competitive differentiator)*	**AWM90000 Series *AWM92100V***
	
Features and Benefits	
• High 12-bit resolution (digital) or high 11-bit resolution (analog) increases the ability to sense small airflow changes, allowing for more precise control of the application ★**Meet high accuracy specifications:** High 2.5% accuracy allows for very precise airflow measurement, often ideal for demanding applications with high accuracy requirements ★**Customizable:** Allows the sensor to be designed to meet specific end-user needs ★**High sensitivity at very low flows:** Allows the customer's application to detect presence or absence of airflow ★**High stability:** Reduces errors due to thermal effects and null shift to provide accurate readings	• Mass flow and low differential pressure sensing • Sensitivity to low flows (0.1 SCCM to 200 SLPM) • Cost effective • Low power consumption • Analog output

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over time, often eliminating need for system calibration after printed circuit board mount, and periodically over time ★ **Low pressure drop:** Low pressure drop typically improves patient comfort in medical applications, and reduces noise and system wear in components such as motors/pumps ★ **Saves customers time and money:** Linear output provides a more intuitive sensor signal than the raw output of basic airflow sensors, often eliminating the need for customers having to linearize the output which can help to reduce production and design costs and implementation time • **Simplifies customer's production requirements:** ASIC-based I^2C digital output compatibility eases integration to micro-processors or micro-controllers, reducing PCB complexity and component count • **Small:** Occupies less space on PCB, allowing easier fit and potentially reducing production costs; PCB size may also be reduced for easier fit into space-constrained applications • **Flexible:** Low 3.3 Vdc voltage option and low power supply allows for battery-driven and other portable applications	• Enhanced response time • Unamplified • Non-compensated (external customer-supplied bypass needed)

Flexible Heater Assembly

Moisture introduced into the air stream is generated by either mist or heated vapor. This is often best accomplished by heating water to a vapor and introducing it into the air stream. This method often has an advantage over the misting method as it creates vapor, as well as heat. These flexible heaters are custom-designed to customer requirements. On-board sensors such as thermistor thermal links and electrical fuses are commonly added. (See Table 2.)

Table 2. Flexible Heater Assembly

Custom Configurations	Features and Benefits
	• Flat, molded-to-shape, spiral wrap, transparent, and high-temperature configurations • Single, multiple or variable Watt densities designed to customize heat output • Variety of manufacturing materials, including silicone and other flexible dielectric components

Magnetic Sensor ICs

The durable SS400 Series is designed to provide enhanced output accuracy for smooth motor control that reduces noise and vibration in motor assembly fan systems. Its small size often reduces replacement costs and allows for design into many compact, automated, lower-cost assemblies. A thermally-balanced integrated circuit that is accurate over a full temperature range is designed to provide proper fan functionality. (See Table 3.)

Table 3. Magnetic Sensor ICs

SS400 Series	Features and Benefits
	• Quad Hall-effect design minimizes effects of mechanical or thermal stress on output, and promotes a stable output • Unipolar, bipolar or bipolar latching magnetics and customizable operate/release points provide application flexibility • Negative compensation slope optimized to match negative temperature coefficient of lower-cost magnets, providing robust design over wide temperature range • Band gap regulation promotes stable operation over supply voltage range • Low power consumption enhances energy efficiency

Humidity Sensors

These sensors may be used to deliver warm and moist air, which often enhances patient comfort. When introducing moisture into the air stream, it must be monitored and controlled. Honeywell's humidity sensors are installed either directly into the air stream or in a parallel branch. The sensor is coupled to a microcontroller designed to measure the humidity of the air stream and to interact with the controller that ensures the correct level of moisture is present. (See Table 4.)

Table 4. Humidity Sensors

Honeywell HumidIcon™ Digital Humidity/Temperature	Features and Benefits (★ = competitive differentiator)

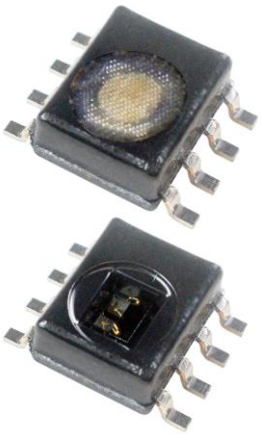
Sensors: HIH6130/6131 Series	
	★ **Industry-leading long-term stability (1.2 %RH over five years):** Minimizes system performance issues, helps support system uptime by eliminating the need to service or replace the sensor during its application life, and eliminates the need to regularly recalibrate the sensor ★ **Industry-leading Total Error Band (TEB) (±5 %RH)** (Over a compensated range of 5 °C to 50 °C [41 °F to 122 °F] and 10% RH to 90% RH): Eliminates individual sensor testing and calibration, supports system accuracy and warranty requirements, helps to optimize system uptime, and provides excellent sensor interchangeability ★ **Industry-leading reliability:** Laser trimmed, thermoset polymer capacitive sensing element's multilayer construction provides resistance to most application hazards ★ **Lowest total cost solution:** Due to the sensor's industry-leading Total Error Band and its being a combined humidity/temperature sensor ★ **True, temperature-compensated digital I^2C output:** Typically allows the customer to remove the components associated with signal conditioning from the PCB ★ **Energy efficient:** Can operate down to 2.3 Vdc, allowing use in low energy and wireless-compatible applications to enhance energy savings and prolong system battery life. The sensor goes into sleep mode when not taking a measurement within the application, consuming only 1 µA of power versus 650 µA in full operation in a battery operated system ★ **Ultra-small SOIC-8 SMD (Surface Mount Device) package:** Allows for flexibility of use ★ **Combined humidity and temperature sensor in one package:** Allows the RH measurement to be temperature compensated and provides a second, standalone temperature sensor output. ★ **Cost-effective tape and reel packaging:** Allows for use in high volume, automated pick-and-place manufacturing, eliminating lead misalignment to the PCB and helping the customer to reduce manufacturing costs ★ **High resolution:** High 14-bit humidity sensor resolution and 14-bit temperature sensor resolution within the application help the user's system detect the smallest RH or temperature change ★ **Wide operating temperature range** of -25 °C to 85 °C [-13°F to 185 °F]: Allows for use in many applications ★ **Optional one or two %RH level alarm outputs:** Provide the user the ability to monitor whether the RH level has exceeded or fallen below pre-determined and critical levels within the application ★ **Multi-function ASIC:** Provides flexibility within the application by lowering or eliminating the risk and cost of OEM calibration ★ **Two configurations:** Increase flexibility of use; HIH6130: no filter, non-condensing; HIH6131: hydrophobic filter and condensation-resistant allow use in many condensing environments

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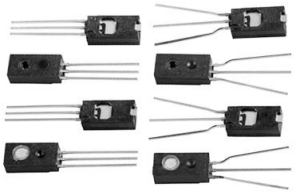
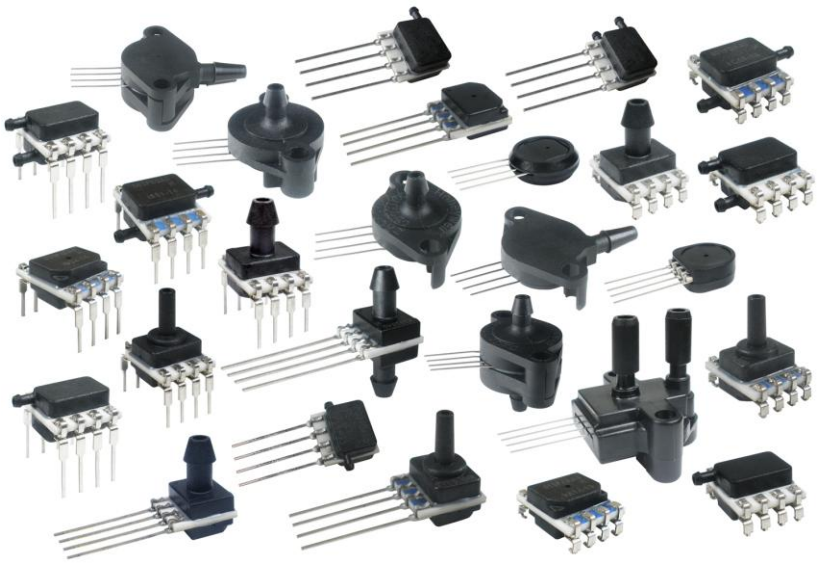
Table 4. Humidity Sensors (continued)

HIH-4000 Series	HIH-4020/4021 Series	HIH-4030/4031 Series	HIH-5030/5031 Series	HCH-1000 Series
				
Features and Benefits				
• Instrumentation-quality RH sensing performance in a competitively priced, solderable SIP • Accurate, fast response • Multilayer construction provides enhanced resistance to wetting, dirt, and common environmental chemicals • Laser trimmed for stable, low drift performance • Factory calibration data designed to provide individually-matched downstream electronics and accuracy • HIH-4020/4021 Series: Available covered/uncovered and filtered/unfiltered for application flexibility		• Multilayer construction designed to provide enhanced resistance to wetting, dirt, and common environmental chemicals. • Available covered, filtered/unfiltered for application flexibility • Surface mount design • Low current draw • Factory calibration data designed to provide individually-matched downstream electronics and accuracy. • Voltage supply: – HIH-4030/4031: 4 Vdc to 5.8 Vdc – HIH-5030/5031: 2.7 Vdc to 5.5 Vdc		• Unbuffered capacitive output for a cost-effective solution • Reduced temperature dependence • Low hysteresis • Long-term stability • Enhanced sensitivity/response

Low Pressure Board Mount Pressure Sensors

These sensors monitor the pressure delivered to the patient in all three PAP machine types. (See Table 5.)

Table 5. Low Pressure Board Mount Pressure Sensors

TruStability® Board Mount Sensors (HSC Series and SSC Series)	Feature and Benefits
	• Temperature compensation and calibration provide an amplified signal, typically allowing removal of components associated with signal conditioning from the PCB, increasing space and reducing associated costs • Industry-leading stability often eliminates need for calibration after PCB mount, and periodically over time • Digital ASIC output in either I^2C or SPI protocols from digital sensors accelerates performance through reduced conversion requirements and the convenience of direct interface to microprocessors and microcontrollers • Multiple packaging, mounting, power, and signal options combine with customized calibration capabilities increases application flexibility

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Temperature Sensors

Discrete Thermistors: Air that is warm and moist helps to provide the patient with a comfortable breathing situation and may reduce sore throats caused by breathing cold, dry air. As such, the temperature of the air delivery system is often monitored and controlled to help ensure that the air stream is maintained at the desired level of warmth. The 192 Series and 194 Series are installed directly into the air stream, and are designed to monitor and control air temperature. The sensor is coupled to a microcontroller designed to monitor air stream temperature and interact with the controller which controls and regulates the temperature of the air stream. Honeywell offers several types of configurations.

The packaged sensors are available as discreet components for customer-built assemblies, or Honeywell can provide a full assembly solution that the customer may simply pigtail into the system. (See Table 6.)

Packaged Temperature Probes: These small, easy to install probe assemblies support and position their thermistor elements within the media to be monitored as well as protect the thermistors against damage in use or handling. The assemblies also help direct thermal or fluid flow evenly across the thermistors for accurate temperature sensing. (See Table 6.)

Table 6. Temperature Sensors

Discrete Thermistors 192 Series, 194 Series	Packaged Temperature Probes 500 Series
	
Features and Benefits	
• Bare leads (192 Series) or insulated leads (194 Series) designed for improved application flexibility • Resistance temperature (R-T) curve interchangeability designed to offer standardization of circuit components and simplification of design/replacement, as well as potential cost savings • Small size often eases use in confined spaces	• Enhanced reliability, precision and stability allow the customer greater flexibility in temperature monitoring and control • Wide operating temperature range of -60 °C to 300 °C [-76 °F to 572 °F] provides application flexibility • Available in wide variety of housing styles and materials, R-T curves, mounting methods, mechanical interface, electrical interface and connector types to meet most application needs

Commercial Thermostats

Bimetallic thermostats may be included in sleep apnea machines as on-board (stand-alone) devices on flexible heaters for temperature control without the need to add associated software or electronics. (See Table 7.)

Table 7. Commercial Thermostats

2450RC Series	Features and Benefits
	• Cost effective • Custom operating temperatures and tolerances to fit customer-specific applications • Wide variety of mounting brackets and terminals increase flexibility within the application • Small product size allows enhanced response to temperature changes

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⚠ WARNING

PERSONAL INJURY

DO NOT USE these products as safety or emergency stop devices or in any other application where failure of the product could result in personal injury.

Failure to comply with these instructions could result in death or serious injury.

WARRANTY/REMEDY

Honeywell warrants goods of its manufacture as being free of defective materials and faulty workmanship. Honeywell's standard product warranty applies unless agreed to otherwise by Honeywell in writing; please refer to your order acknowledgement or consult your local sales office for specific warranty details. If warranted goods are returned to Honeywell during the period of coverage, Honeywell will repair or replace, at its option, without charge those items it finds defective. **The foregoing is buyer's sole remedy and is in lieu of all other warranties, expressed or implied, including those of merchantability and fitness for a particular purpose. In no event shall Honeywell be liable for consequential, special, or indirect damages.**

While we provide application assistance personally, through our literature and the Honeywell web site, it is up to the customer to determine the suitability of the product in the application.

Specifications may change without notice. The information we supply is believed to be accurate and reliable as of this printing. However, we assume no responsibility for its use.

⚠ WARNING

MISUSE OF DOCUMENTATION

- The information presented in this application note is for reference only. Do not use this document as a product installation guide.
- Complete installation, operation, and maintenance information is provided in the instructions supplied with each product.

Failure to comply with these instructions could result in death or serious injury.

SALES AND SERVICE

Honeywell serves its customers through a worldwide network of sales offices, representatives and distributors. For application assistance, current specifications, pricing or name of the nearest Authorized Distributor, contact your local sales office or:

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