

## Application Note

# Sensors and Flexible Heaters in Sleep Apnea Machines

### 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.



Sleep apnea machine

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).

### 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 1.)

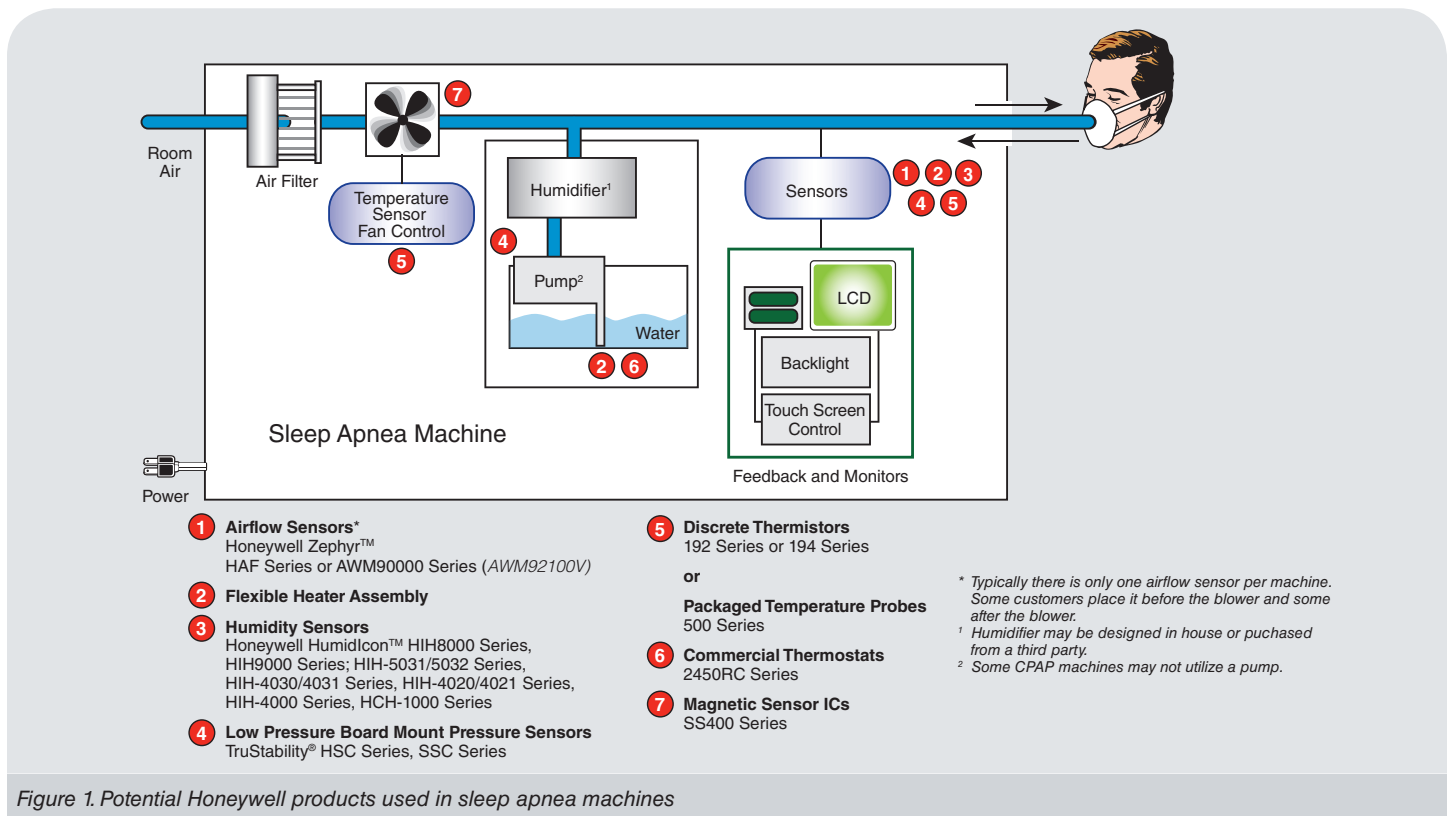


Figure 1. Potential Honeywell products used in sleep apnea machines

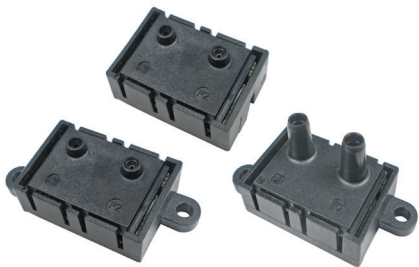
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### AIRFLOW SENSORS

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.



Honeywell Zephyr™ Analog or Digital Airflow Sensors (HAF Series)  
±50 SCCM to ±750 SCCM

#### Features and Benefits (★ = competitive differentiator)

- 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 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<sup>2</sup>C 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



Honeywell Zephyr™ Digital Airflow Sensors (HAF Series)  
10 SLPM to 300 SLPM

#### Features and Benefits (★ = competitive differentiator)

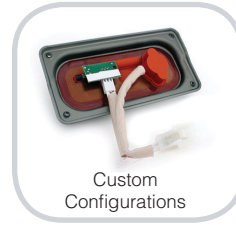
- ★ Industry's smallest Total Error Band (TEB) allows for precise airflow measurement, often ideal for demanding applications with high accuracy requirements
- High accuracy is ideal for use in demanding applications
- Fast response time allows the customer's application to respond quickly to airflow change, important in critical medical (e.g., anesthesia) and industrial (e.g., fume hood) applications
- High stability reduces errors due to thermal effects and null shift to provide accurate readings over time and often eliminating the need for system calibration after PCB mount and periodically over time
- High sensitivity at very low flows provides a fast response time at the onset of cessation of flow
- High 12-bit resolution increases the ability to sense small airflow changes, allowing customers to more precisely control their application
- ★ Wide airflow range measures mass flow with standard flow ranges of 10 SLPM, 15 SLPM, 20 SLPM, 50 SLPM, 100 SLPM, 200 SLPM or 300 SLPM, or custom flow ranges, increasing the options for integrating the sensor into the application
- ★ Choice of port styles (manifold mount, 22 mm OD tapered male fitting, and G 3/8 female threaded fitting) provide flexibility to choose the pneumatic connection that is best for the customer's application
- ★ Linear output provides a more intuitive sensor signal than the raw output of basic airflow sensors, which can help

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reduce production costs, design, and implementation time

- Wide supply voltage range: flexible regulated power circuit (3 Vdc to 10 Vdc) gives the designer the flexibility to choose the supply voltage that works best in the system
- ASIC-based I<sup>2</sup>C digital output simplifies integration to microprocessors or microcontrollers, reducing PCB complexity and component count
- Factory or custom calibration for multiple gas types: can be factory calibrated for many gases, such as dry air, helium (He), argon (Ar), nitrogen (N<sub>2</sub>), nitrous oxide (N<sub>2</sub>O), and carbon dioxide (CO<sub>2</sub>), or custom calibrated for the end customer, eliminating the need to implement gas correction factors
- RoHS-compliant materials meet Directive 2002/95/EC



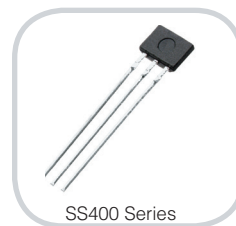
### Features and Benefits

- 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

### HALL-EFFECT 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.



### 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



### Features and Benefits

- Mass flow and low differential pressure sensing
- Sensitivity to low flows (0.1 SCCM to 200 SLPM)
- Cost effective
- Low power consumption
- Analog output
- 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.

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## Sensors and Flexible Heaters in Sleep Apnea Machines

### 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.



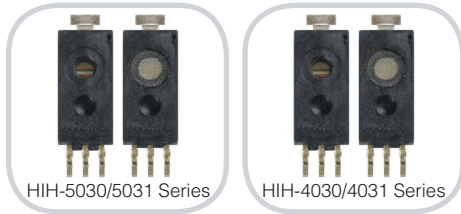
#### Features and Benefits (★ = competitive differentiator)

- ★ 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
  - Eliminates the need to regularly recalibrate the sensor in the application, which can be inconvenient and costly
- ★ Industry-leading reliability (MTTF 9,312,507 HR):

Thermoset-polymer capacitive sensing element's multilayer construction provides resistance to most application hazards such as condensation, dust, dirt, oil, and common environmental chemicals, which help provide industry-leading reliability.
- ★ Lowest total cost solution: Delivers the lowest total cost solution due to the sensor's industry-leading combined humidity/temperature sensor
- Combined humidity and temperature sensor: Allows the RH measurement to be temperature compensated, and provides a second, standalone temperature sensor output; allows the user to purchase one sensor instead of two
- ★ Energy efficient:
  - Low supply voltage: Can operate down to 2.3 Vdc, which allows use in low energy and wireless-compatible applications to enhance energy savings and prolong system battery life
  - Low power consumption: The sensor goes into sleep mode when not taking a measurement within the application, consuming only 1  $\mu$ A versus 650  $\mu$ A in full operation in a battery operated system; sleep mode helps maximize battery life, reduces power supply size, and reduces the application's overall weight
- 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 relative humidity or temperature change
- ★ True, temperature-compensated digital I<sup>2</sup>C or SPI output: Typically allows the customer to remove the components associated with signal conditioning from the PCB to free up space and reduce costs associated with those components (e.g., acquisition, inventory, assembly). True, temperature-compensated digital I<sup>2</sup>C or SPI output often eliminates problems that could occur from having multiple signal conditioning components across the PCB, as well as simplifies integration to the microprocessor, eliminating the need for customer-implemented, complex signal conditioning.
- ★ Housing style: SOIC-8 SMD (Surface Mount Device) or SIP 4 Pin; ultra small size allows for flexibility of use within the application, occupies less space on the PCB, and typically simplifies placement on crowded PCBs or in small devices; industry standard design simplifies design-in
- Filter: Available with hydrophobic filter and condensation-resistance, allowing for use in many condensing environments, or without hydrophobic filter, non-condensing
- Tape and reel: 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
- Wide operating temperature range: -40 °C to 125 °C [-40 °F to 257 °F] allows for use in many applications
- Optional one or two %RH level alarm outputs: Provides the ability to monitor whether the RH level has exceeded or fallen below pre-determined and critical levels within the application
- Multi-function ASIC: Delivers flexibility within the application by lowering or eliminating the risk and cost of OEM calibration
- RoHS and WEEE compliant, halogen-free

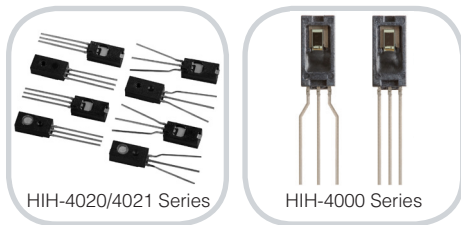
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### Features and Benefits

- 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-5030/5031: 2.7 Vdc to 5.5 Vdc
  - HIH-4030/4031: 4 Vdc to 5.8 Vdc



### 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

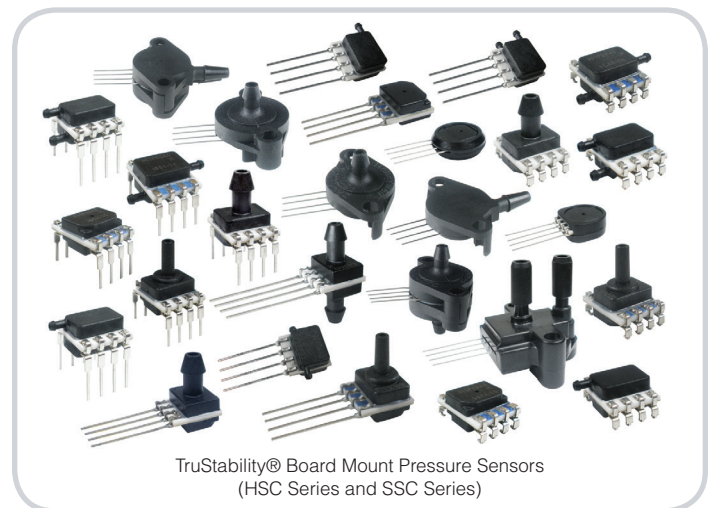


### Features and Benefits

- Unbuffered capacitive output for a cost-effective solution
- Reduced temperature dependence
- Low hysteresis
- Long-term stability
- Enhanced sensitivity/response

### PRESSURE SENSORS

These sensors monitor the pressure delivered to the patient in all three PAP machine types.



### Features 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<sup>2</sup>C 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 to increase flexibility

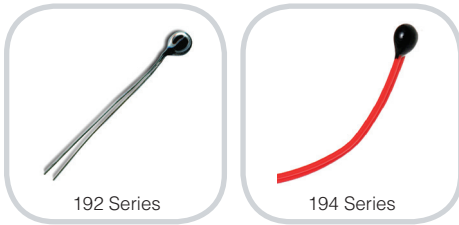
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### TEMPERATURE SENSORS

**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.



- 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

**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.



- 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.



#### 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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## Sensors and Flexible Heaters in Sleep Apnea Machines

### Find out more

To learn more about Honeywell's sensing and control products, call **1-800-537-6945**, visit **sensing.honeywell.com**, or e-mail inquiries to **info.sc@honeywell.com**

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