

# SENSORS IN HEMODIALYSIS MACHINES

Application Note

Honeywell manufactures many sensors which may be used in hemodialysis machines (see Figure 1). This application note shows how these sensors provide dialysate cartridge presence/absence detection, fluid pressure/flow and temperature measurement, and smooth motor control output.

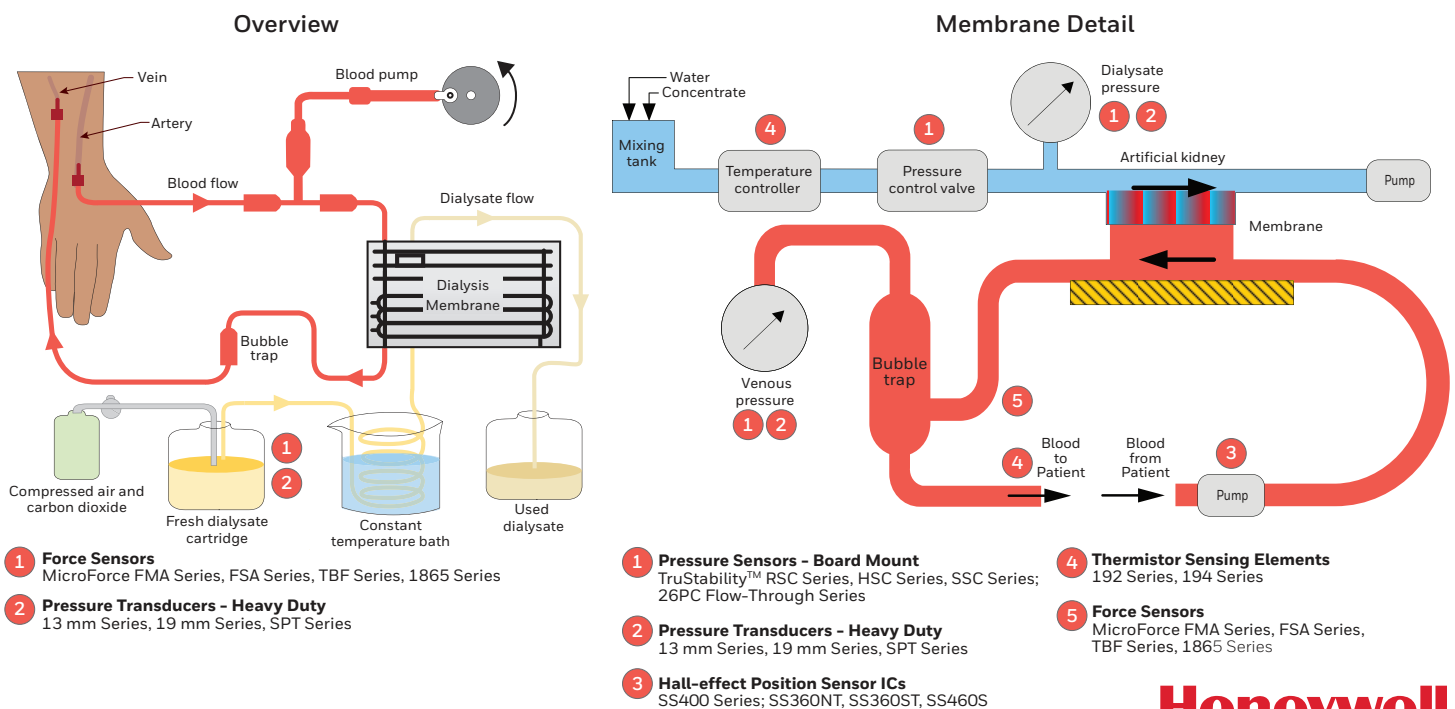
## INTRODUCTION

Hemodialysis machine treatments replace some kidney functions by removing waste and fluid from the bloodstream via diffusion and osmosis of solutes and fluid across a semipermeable dialysis membrane.

Blood in one compartment is pumped along one side of the membrane while a dialysate (a crystalloid solution that acts as a sponge for impurities) is pumped along the other side, in a separate compartment, in the opposite direction.

Ultrafiltration occurs by increasing the hydrostatic pressure across the membrane by applying a negative pressure to the dialysate compartment of the dialyzer. This pressure gradient causes water and dissolved solutes to move from the blood to the dialysate. The cleansed blood returns via the circuit back to the body.

**FIGURE 1. HEMODIALYSIS OVERVIEW AND MEMBRANE DETAIL SHOWING POTENTIAL HONEYWELL PRODUCTS USED**



**Honeywell**

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## FORCE SENSORS

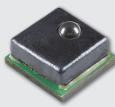
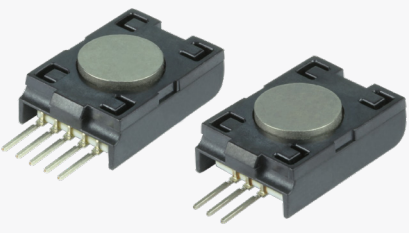
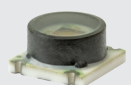
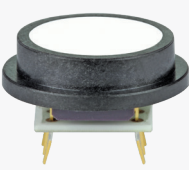
### MicroForce FMA Series, 1865 Series, FSA Series, TBF Series

These force sensors (see Table 1) may be used to detect the presence or absence of a fresh dialysate cartridge before the dialysis machine can be used. They are used in a non-invasive manner and require no disinfection or sterilization before reuse. Other potential uses for Honeywell's force sensors include monitoring the flexible tubing pressure of the dialysate to detect whether the pressure exceeds a specified level, and monitoring the weight of the dialysate to detect whether there is a sufficient amount of dialysate in the fresh dialysate cartridge.

#### Benefits to Customer

- **Reliable:** Enhanced quality and reliability (<100 ppm).
- **Sensitive:** Enhanced sensitivity to force changes enables early detection of occlusion, enhancing patient safety.
- **Stable:** Ability to detect occlusion accurately over time provides enhanced stability and low drift.

**TABLE 1. FORCE SENSORS**

MICROFORCE FMA SERIES	FEATURES	
	<ul style="list-style-type: none"> <li>• Small form factor: 5 mm x 5 mm [0.20 in x 0.20 in]</li> <li>• Accuracy: ±2 %FSS typical</li> <li>• SPI- or I<sup>2</sup>C-compatible digital output</li> <li>• Fully calibrated and temperature compensated over a temperature range of 5°C to 50°C [41°F to 122°F]</li> <li>• Available in a wide variety of standard and configurable force ranges</li> </ul>	<ul style="list-style-type: none"> <li>• Overforce: 3X force range</li> <li>• Supply voltage: 3.3 Vdc typ. or 5.0 Vdc typ.</li> <li>• Low power consumption: 14 mW</li> <li>• Enhanced part-to-part repeatability</li> <li>• Enhanced reliability</li> <li>• Stable, stainless steel sphere interface</li> <li>• Internal diagnostic functions available</li> <li>• REACH and RoHS compliant</li> </ul>
FSA SERIES	FEATURES	
	<ul style="list-style-type: none"> <li>• Wide variety of force ranges:               <ul style="list-style-type: none"> <li>- Newton (N): 5, 7.5, 10, 15, 20, 25</li> <li>- pound (lb): 1, 1.5, 2, 3, 5</li> <li>- gram (g): 500, 750</li> <li>- kilogram (kg): 1, 2</li> </ul> </li> <li>• Total Error Band: ±5 %FSS</li> <li>• Accuracy: ±3 %FSS</li> <li>• Ratiometric analog, or SPI- or I<sup>2</sup>C-compatible digital output</li> <li>• Fully calibrated and temperature compensated over a temperature range of 5°C to 50°C [41°F to 122°F]</li> </ul>	<ul style="list-style-type: none"> <li>• Overforce: 15 lb [6804 g]</li> <li>• Supply voltage: 3.3 Vdc typ. or 5.0 Vdc typ.</li> <li>• Low power consumption: 13 mW (analog) or 20 mW (digital)</li> <li>• Excellent part-to-part repeatability</li> <li>• Enhanced reliability</li> <li>• Stable interface plunger</li> <li>• Internal diagnostic functions available</li> <li>• REACH and RoHS compliant</li> </ul>
TBF SERIES BASIC	FEATURES	
	<ul style="list-style-type: none"> <li>• Solid state, piezoresistive, gage pressure transducer mounted in a plastic package; special silicone gel transmits applied pressure to a silicon piezoresistive MEMS die mounted on a robust ceramic substrate</li> <li>• For applications where force is applied by a flexible membrane to the sensor, such as infusion pumps, the precision height silicone diaphragm provides long life and is a reliable replacement for older force or load cell transducers</li> <li>• Silicone rubber diaphragm allows compatibility with some liquid media applications</li> </ul>	<ul style="list-style-type: none"> <li>• Small footprint (7 mm x 7 mm x 3,89 mm)</li> <li>• Wide pressure range: 1 bar to 10 bar   100 kPa to 1 MPa   15 psi to 150 psi</li> <li>• Tight accuracy: ±0.15 %FSS</li> <li>• Wide operating temperature range: -20°C to 85°C [-4°F to 185°F]</li> <li>• Low power consumption</li> <li>• Stable offset voltage</li> <li>• Not sensitive to mounting orientation</li> <li>• RoHS2 compliance</li> </ul>
1865 SERIES	FEATURES	
	<ul style="list-style-type: none"> <li>• Silicon pressure/force interface diaphragm</li> <li>• Pressure measurement for liquid media</li> <li>• Medical-grade materials</li> <li>• 8-pin DIP electrical connection</li> <li>• Choice of voltage or constant current excitation</li> <li>• Temperature compensated</li> <li>• Enhanced performance</li> </ul>	<ul style="list-style-type: none"> <li>• Reliable replacement for older force or load cell transducers</li> <li>• Silicone rubber diaphragm allows potential compatibility with liquid media applications</li> <li>• Laser-trimmed compensation may be specified to operate with a constant current or voltage supply</li> </ul>

## PRESSURE SENSORS AND TRANSDUCERS

**Board Mount Pressure Sensors: TruStability™ RSC Series, HSC Series, SSC Series; 26PC Flow-Through Series (26PCFEP5G40)**  
**Heavy Duty Pressure Transducers: 13 mm Series, 19 mm Series, SPT Series**

Honeywell's TruStability and 26PC Series flow-through board mount pressure sensors (see table 2) are designed to provide enhanced reliability and may be used to obtain a direct, in-line continuous dialysate and venous pressure measurement in the dialysis membrane without interrupting flow. The easy-to-sterilize package eliminates the need for an additional pressure tap and/or manifold, minimizing the unused space in the flow measurement path, which helps to prevent bacteria contamination and simplifies sterilization.

The 13 mm Series, 19 mm Series, and SPT Series heavy duty pressure transducers (see Table 3), when located in a fresh dialysate cartridge, may be used to monitor pressure in the flexible tubing that carries blood or dialysate to provide continuous feedback of line pressures and pump control. These sensors may also be used to perform the same function as the 26PC Flow-Through Series in the dialysis membrane.

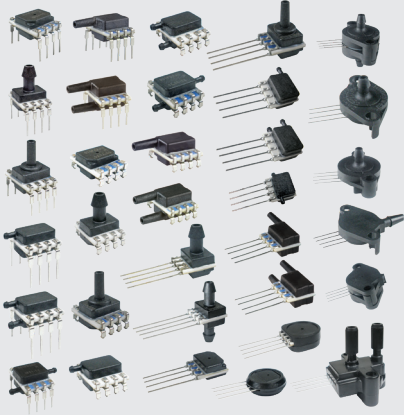
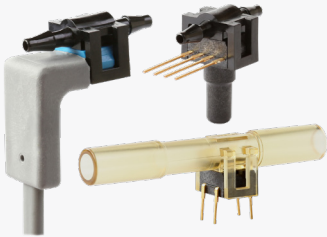
### Benefits to Customer

- **Accurate:** Provides stable performance with low drift over time, allowing accurate pressure monitoring of fluid and blood flow to help maintain the pressure in the desired range, improving treatment efficiency and reducing the time it takes to remove fluid from the peritoneum.
  - TruStability sensors' accuracy is a result of precise manufacturing processes, and temperature compensation and calibration. The RSC Series provides high 24-bit resolution and the Total Error Band after auto zero is as low as  $\pm 0.25\%$ FSS. The Total Error Band of the HSC Series and SSC Series depends on the pressure range, with the HSC Series as low as  $\pm 1\%$ FSS and the SSC Series as low as  $\pm 2\%$ FSS.



- The 26PC Flow-Through Series offers accuracy of  $\pm 2\%$ FSS; the 13 mm Series, 19 mm Series, and SPT Series offer accuracy of  $0.25\%$ FSS.

- **Easy to design in:** Customization with desired pressure ranges, connections, calibration, and temperature compensation minimizes customer's design-in effort.
- **Extended life:** Product availability throughout the customer's product life cycle minimizes the need to repeat the design-in process and requalifying/resubmitting for regulatory approval.
- **Small:** Small package reduces the number of components needed to implement the sensor, enabling reduction in size and weight.
- **Stable:** Stability is a measure of how little the output signal of the pressure sensor will change from measurement to measurement.

**TABLE 2. BOARD MOUNT PRESSURE SENSORS**

TRUSTABILITY™ RSC SERIES, HSC SERIES, SSC SERIES	FEATURES	
	<ul style="list-style-type: none"> <li>• 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</li> <li>• Enhanced stability often eliminates need for calibration after PCB mount, and periodically over time</li> <li>• 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</li> </ul>	<ul style="list-style-type: none"> <li>• Multiple packaging, mounting, power, and signal options combine with customized calibration capabilities increases application flexibility</li> <li>• RSC Series provides high 24-bit resolution and Total Error Band as low as <math>0.25\%</math>FSS</li> </ul>
26PC FLOW-THROUGH SERIES	FEATURES	
	<ul style="list-style-type: none"> <li>• Flow through design in miniature, plastic package (versus stainless steel package) designed to provide a reduced-cost alternative</li> <li>• Integrated flow through design eliminates need for many additional connections and parts</li> <li>• Enhanced reliability due to fewer connections and parts</li> </ul>	<ul style="list-style-type: none"> <li>• Robust media compatibility requires no gel coating</li> <li>• Calibrated and temperature compensated with true wet/wet differential sensing for increased application flexibility</li> </ul>

**TABLE 3. HEAVY DUTY PRESSURE TRANSDUCERS**

13 MM SERIES AND 19 MM SERIES	FEATURES
	<ul style="list-style-type: none"> <li>• Small size for use on portable equipment</li> <li>• High impedance and low current draw for battery operation</li> <li>• Constant current for use with 4 mA to 20 mA amplifier integrated circuits</li> <li>• Oil-free, isolated sensor reduces risk of leakage and contamination</li> </ul>
SPT SERIES	
	<ul style="list-style-type: none"> <li>• Flush mount, non-corrugated diaphragm for easy sanitation</li> <li>• Stainless steel package for easy disinfection</li> <li>• Calibrated and temperature compensated for enhanced performance</li> </ul>

**HALL-EFFECT POSITION SENSOR ICs**

**SS490 Series; SS360NT, SS360ST, SS460S**

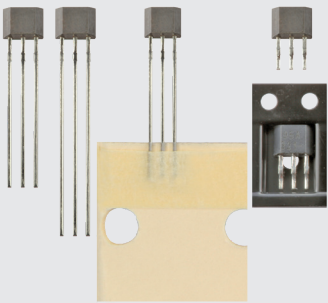

Hall-effect position sensor ICs (see Table 4) are designed to provide reliable, accurate output for smooth motor control that reduces noise and vibration in the machine’s motor assembly and improves its efficiency. Their solid state reliability often reduces repair and maintenance costs, and its small size allows for design into many compact, automated, lower-cost assemblies. A thermally-balanced integrated circuit provides consistent operation over the full temperature range.

**Benefits to Customer**

- **Accurate:** For linear displacement and current sensing, analog Hall-effect sensors provide accurate and linear output, enabling an extended sensing range (SS490 Series).

- **Cost-effective:** Small sensor size allows for compact designs and automated, lower-cost assemblies and minimizes replacement costs.
- **Energy-efficient:** Hall-effect sensors consume little energy and help improve motor efficiency.
- **Quiet:** Reliable, accurate sensor output for smooth motor control enables low audible noise, and reduces motor vibration.

**TABLE 4. HALL-EFFECT POSITION SENSOR ICs**

SS490 SERIES	FEATURES	
	<ul style="list-style-type: none"> <li>• Quad Hall-effect design minimizes effects of mechanical or thermal stress on output, and promotes a stable output</li> <li>• Unipolar, bipolar or latching magnetics and customizable operate/release points</li> <li>• Negative compensation slope optimized to match negative temperature coefficient of lower-cost magnets, providing robust design over wide temperature range</li> </ul>	<ul style="list-style-type: none"> <li>• Band gap regulation promotes stable operation over supply voltage range</li> <li>• Low power consumption enhances energy efficiency</li> </ul>
S360NT, S360ST, SS460S	FEATURES	
	<ul style="list-style-type: none"> <li>• Fastest response time in its class</li> <li>• No chopper stabilization</li> <li>• High sensitivity</li> <li>• Latching magnetics</li> <li>• Built-in reverse voltage</li> <li>• Durable design</li> <li>• RoHS-compliant material meets Directive 2002/95</li> </ul>	

## THERMISTOR SENSING ELEMENTS

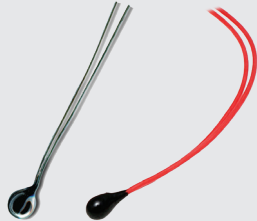
### 192 Series, 194 Series

Temperature directly affects the permeation rate across the dialysis membrane. The 192 Series and 194 Series thermistor sensing elements (see Table 5) provide temperature measurement for enhanced control of this variable. The sensor is coupled to a microcontroller designed to monitor the temperature of the operation and to interact with the controller to help regulate the temperature of the system. Honeywell offers several configurations. These packaged sensors are available as discreet components for custom-built assemblies, as well as full assembly solutions that the customer may simply pigtail into the system.

### Benefits to Customer

- **Cost-effective:** Resistance temperature curve interchangeability designed to offer standardization of circuit components and simplification of design/replacement enhances cost-effectiveness.
- **Flexible:** Bare leads (192 Series) or insulated leads (194 Series) are designed to provide application flexibility.
- **Small:** Small size often eases use in confined spaces.

TABLE 5. THERMISTOR SENSING ELEMENTS

192 SERIES, 194 SERIES	FEATURES
	<ul style="list-style-type: none"><li>• Bare leads (192 Series) or insulated leads (194 Series)</li><li>• Resistance temperature (R-T) curve interchangeability designed to offer standardization of circuit components and simplification of design/replacement, as well as potential cost savings</li><li>• Small size often eases use in confined spaces</li></ul>

## FOR MORE INFORMATION

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