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How to minimize warm-up drift in pressure sensors

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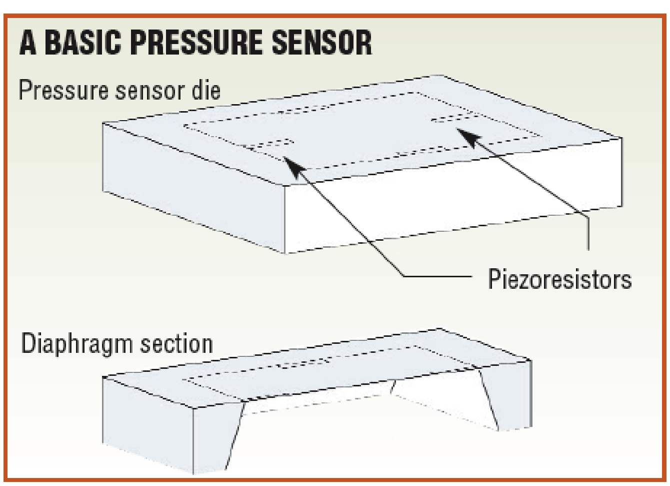
An assortment of sensors features the 0.025-in. H20 Full Scale A-package (top) and a range of mini packages. The A-package accurately reads exceedingly low pressures. The devices are for drug delivery, respiratory, and similar applications where physical size is not a constraint. Mini packages target devices requiring a smaller sensor such as for measuring oxygen in a medical device.

Warm-up drift in pressure sensors makes their readings vary until systems reach operating temperature. It's usually of little concern. However, such drift is unacceptable in hospital respirators, spirometry equipment, neonatal monitors, and similar devices requiring high accuracy at all times. Examining a basic piezoresistive pressure sensor helps to understand the effect of warm-up drift.

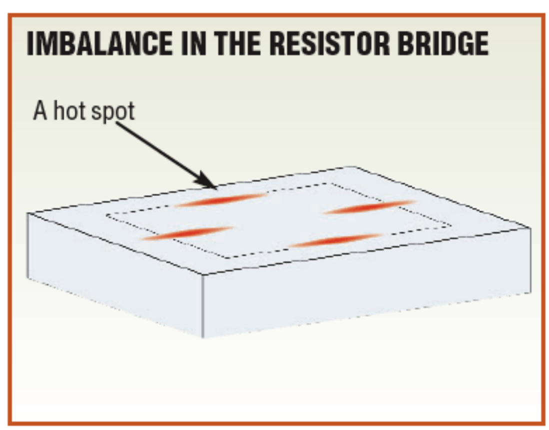
The sensor is made of a body, or "die," and a thin silicon diaphragm with four piezoresistors on the surface. The piezoresistors change resistance in response to stress. They are generally arranged in a bridge configuration and are precisely located on the diaphragm surface to maximize the response to diaphragm deflection. This in turn maximizes the response to a pressure differential across the diaphragm.

Warm-up shift

There are two primary sources of warm-up drift in a basic pressure sensor. One is the warm-up shift of the sensing element. While the system is reaching operating tempera-



A basic pressure sensor is made of a die and a diaphragm with four piezoresistors on the surface.



Thermal hot spots on the die and diaphragm surface (orange lines) cause an imbalance in the resistor bridge.

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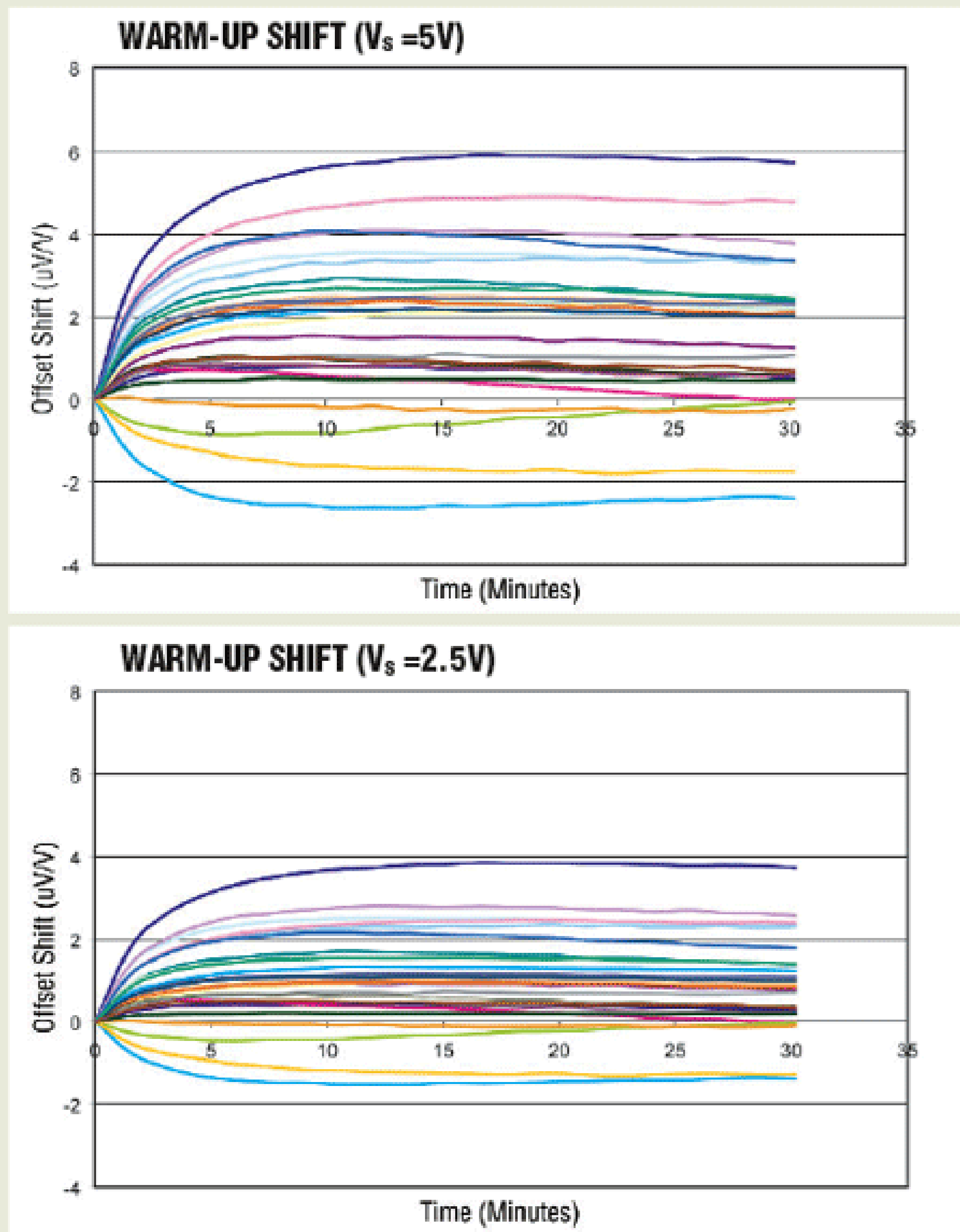
ture, surface temperature and resultant thermal hot spots (surface contribution) on the die and diaphragm surface cause an imbalance in the resistor bridge. The temperature rise of the resistor-sensing element is proportional to the dissipated power and therefore proportional to the square of the excitation voltage of the sensor ($\Delta T \alpha V^2$).

Thus, reducing the excitation voltage by a factor of two reduces the sensing element temperature rise by a factor or four and, consequently, the warm-up surface condition is reduced by a factor of four. Since the signal level of the sensor is also reduced by a factor



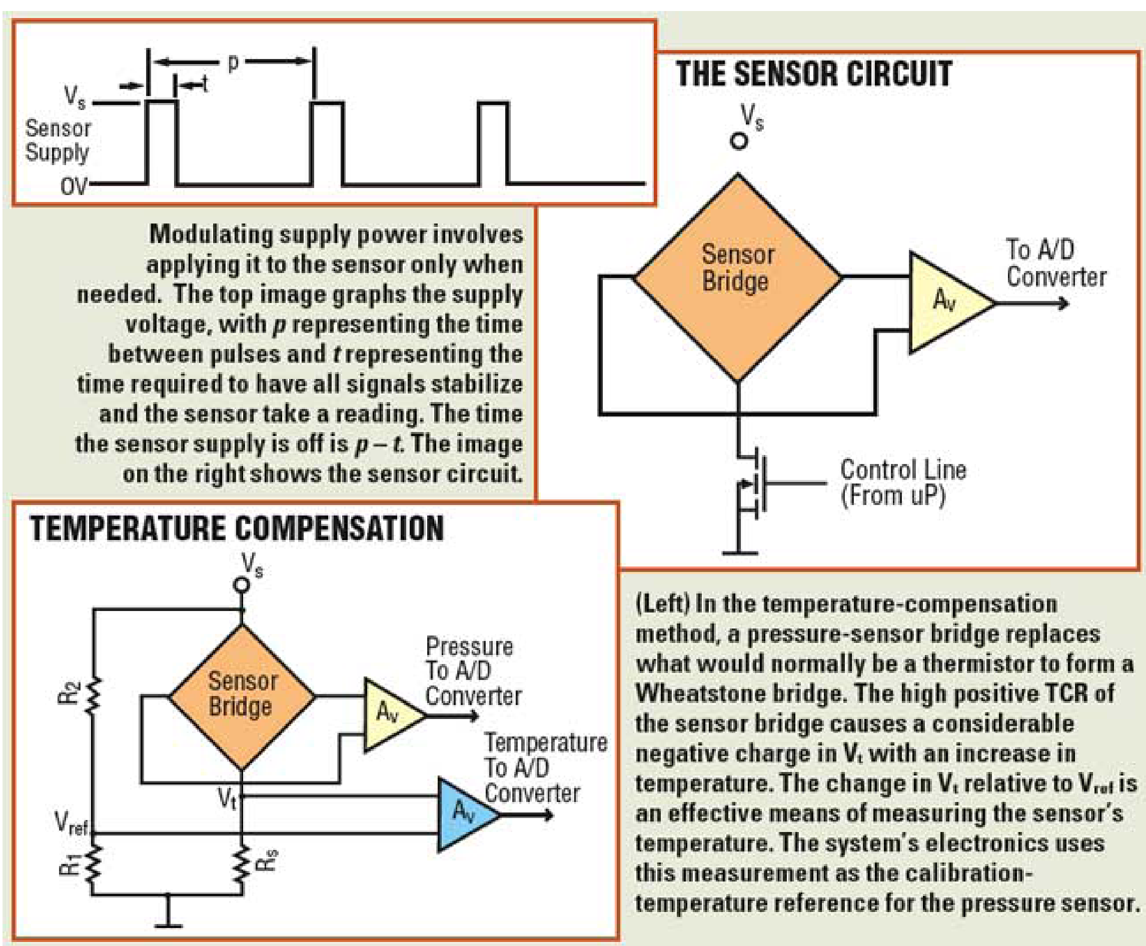
The top graph is a sampling of sensors with a 5 V supply voltage. The bottom graph is the same sampling with a 2.5 V supply voltage. The difference between the two graphs shows how much reducing the supply voltage reduces the surface contribution of warm-up drift. The different colored lines represent different sensors.

of two (with the reduced supply voltage), the overall effect is a reduction in surface contribution warm-up error by a factor of two. However, reducing the sensor power supply adversely affects the system electronic noise level.

An alternate and preferred approach to reducing supply voltage modulates the sensor supply as required by the system bandwidth. In other words, apply power to the sensor only when needed. This reduces power to the sensor to the time average (duty-cycle) applied and, hence, reduces warm-up drift. The method is slightly more sophisticated but can provide excellent results and without affecting system noise level.

Here the period, *p*, between power pulses for an application is the time the power is off plus the time the power is on. This is the time required to have all signals stabilize and the sensor to take a reading.

For example, consider a device that requires readings every 500 ms, has a settling time of 4 ms, and has a signal-acquisition time of 1 ms. The average power to the sensor is only about 1% ([1 ms + 4 ms]/500 ms) of the power applied as compared to a non-modulated system.



Modulating supply power involves applying it to the sensor only when needed. The top image graphs the supply voltage, with *p* representing the time between pulses and *t* representing the time required to have all signals stabilize and the sensor take a reading. The time the sensor supply is off is *p – t*. The image on the right shows the sensor circuit.

(Left) In the temperature-compensation method, a pressure-sensor bridge replaces what would normally be a thermistor to form a Wheatstone bridge. The high positive TCR of the sensor bridge causes a considerable negative charge in V_t with an increase in temperature. The change in V_t relative to V_{ref} is an effective means of measuring the sensor's temperature. The system's electronics uses this measurement as the calibration-temperature reference for the pressure sensor.

Of course, the period depends on an application's sampling requirements. It's important that p and on time t remain constant because of subtle surface charges. However, this is a minor constraint considering the benefits of modulating the sensor supply.

Temperature-compensation technique

Another source of warm-up drift is actually more a perceived characteristic and is related to the system's temperature-compensation technique. Systems often have an external temperature sensor for use in calibrating the pressure sensor for the effects of temperature. Such dual-sensor systems have a temperature gradient between the external device and the surface temperature of the diaphragm. The time it takes for a temperature gradient to stabilize is perceived as warm-up drift.

Minimizing this effect is accomplished by using the sensor resistance (bridge resistance-change with temperature) as the temperature-sensing element. Here the pressure-sensor bridge replaces what would normally be a thermistor (a type of resistor used to measure temperature changes) in a circuit that effectively becomes a Wheatstone bridge.

The sensor bridge has a high positive temperature coefficient of resistance (TCR) so an increase in temperature causes an increasingly negative charge in the signal output voltage (V_t) of the temperature-monitoring portion of the circuit. The change in V_t relative to the reference voltage (V_{ref}) is an effective measurement of the sensor temperature itself. The system electronics uses this measurement as the calibration-temperature reference for the pressure sensor. This eliminates the perceived warm-up drift because an external temperature sensor is not involved, so there is no thermal gradient. The good news is that modulating supply and temperature-compensation methods can be used together to almost eliminate the effect of warm-up drift.

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