The Use of Inference to Improve Response Time in a Pressure Sensing System

Certain control applications require a device that can respond very quickly to changes in the applied pressure. Examples include compressor and turbine controls, as well as some safety shutdown systems. These applications often use a pressure transmitter that measures the applied pressure and generates an analog signal that varies in proportion to the pressure.

A bid specification for those applications might require the device to respond to 63.2% of a pressure step (a standard measure known as 1 Tau) within 150 milliseconds. Although those applications might make up a small percentage of the total market, suppliers of measurement devices can be locked out of large jobs if their pressure transmitter cannot meet that bid requirement.

Confronted with that sort of marketing edict, design engineers often face the need to balance trade-offs. Speeding up the measurement system would satisfy some users' needs, but aspects of the new design might introduce undesirable side efforts. In particular, reducing delays in the sensing system can allow more process noise to sneak through to the measurement.

With some systems the problem can be even more daunting. The mechanical elements of certain differential pressure sensors can take more than 125 milliseconds to produce a 1 Tau response to a pressure step. When the remaining electrical and software components of the system are taken into account, the total response time can be as high as 350 milliseconds.

This paper describes an approach that can meet the marketing requirement without making any significant changes to the sensing system. To understand how the solution works, it is helpful to know a little more about the structure of some differential pressure sensor systems.

Consider a system that contains two diaphragms that are exposed to the user's process. Pressure acting on those diaphragms is applied to fluid-filled reservoirs that transmit the pressure to a silicon strain gauge that is in a bridge circuit. The deflection of the diaphragms change in response to a pressure step, and the fill fluid moves within the reservoirs. The sensor takes a little time to overcome inertia and reach a new equilibrium. The motion of those parts of the system accounts for the 125 milliseconds of mechanical response time.

The strain gauge is an electrical component that varies its resistance in response to changing pressure. A voltage is applied to the bridge circuit containing the strain gauge and several fixed resistors. The voltage out of the bridge changes in response to a pressure step. The voltage change is intentionally slowed by electrically damping the signal. This helps to reduce the noise that is inherent in electrical systems, but the damping adds to the response time.

The computer system digitizes a set of voltages, including the voltage out of the bridge. The computer massages the resulting set of digitized readings using a complex algorithm to produce the measured pressure value. It takes time for the analog-to-digital converter to cycle through all of the sensor's voltages, and additional time for the computer to complete the calculations. The measurement value is scaled to drive an analog output that varies from 4 to 20 milliamps. This signaling method conforms to a standard that is used in the process control industries. Changes in the milliamp output signal are also damped to reduce noise.

The designers understand how each element of the system reacts to applied pressures. That knowledge is used to develop a model that accurately reflects the way that the sensor operates. The model describes the way that pressure deflects the diaphragms, the way that the fill fluid moves, and how the strain gauge reacts to applied pressures. It also accounts for the contribution of the electrical damping components. Every part of the system has been tuned to produce a final milliamp output signal that meets specific accuracy and noise specifications.

The system as it stands cannot be easily tweaked to meet the faster response time requirement. There are things that could be changed to improve the situation, of course. For example, a less viscous fill fluid could be used, or some of the electronic damping that intentionally slows the circuits' response could be removed. The potential downside of those changes is easy to understand: Field-proven sensors are often backed by millions of hours of cumulative operation that show that the system is reliable. Messing with that system would introduce risk and require the development of a new, unproven model. In addition, changes made to improve the response time for a small subset of customers could easily have negative consequences for the overwhelming majority of customers that don't need the faster response time.

A unique, alternate approach has been used to accurately respond to pressure steps much more quickly than the sensor reacts. The solution, called "Inferential Sensing", is based upon the concept that the sensing system responds to changes in the applied pressure in a manner that is very highly repeatable. The new approach embeds a model that mimics that response in software. Using this technique, it is possible to calculate the magnitude of an applied step long before the sensing system has fully responded to the change in the applied pressure.

The computer analyzes the readings as the sensor begins to respond to a pressure step. The rate at which the readings change provides an unambiguous indication of the magnitude of the pressure step.

In essence, the sensor is trying to indicate what the applied pressure is, but it cannot react faster than a certain rate. Inferential sensing does not “predict” or “guess” the value of the applied pressure. Instead the model, which already includes knowledge of the way that the sensor reacts, is extended to include the time dimension. In this way it is possible to infer the applied pressure by watching how the sensor’s output changes as it begins to respond to the change in the applied pressure. Inferential sensing allows the system to provide 1 Tau response, often in much less than 100 milliseconds, when the sensor’s response may only reflect about 15% of the full pressure step.

The complexity of an inferential sensing model is highly dependent upon the details of the mechanical and electrical subsystems that are being modeled. In systems similar to the differential pressure sensor, the model may need to take into account the starting point of the step because that defines the initial positions of the diaphragms. The model may need to include information about the direction of the step because the mechanical motion from lower to higher pressure may not be the same as the reverse step. Many other variables may be relevant, including the sensor temperature and whether the pressure step travels through the neutral (zero pressure) position.

The inferential sensing process has been proven to work extremely well in practice, but it is not always desirable. In particular, the presence of high levels of noise in the user’s process can sometimes allow it to act as a noise amplifier. In noisy processes the inferential sensing algorithm can easily be disabled, causing the system to revert to the normal response characteristics of the sensor. The user can be provided with a configuration option that allows field selection of whether the inferential sensing mechanism should be on or off.

This solution offers “the best of both worlds”: A pressure transmitter that can provide fast response when it is needed without negatively impacting the response characteristics when a slower response is acceptable.

The technology described in this white paper
*is the subject of one or more patent applications**
that have been filed in the United States and elsewhere.
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