time for a solution

By John Monteith

TDC technology provides accurate high-resolution flow & level measurements

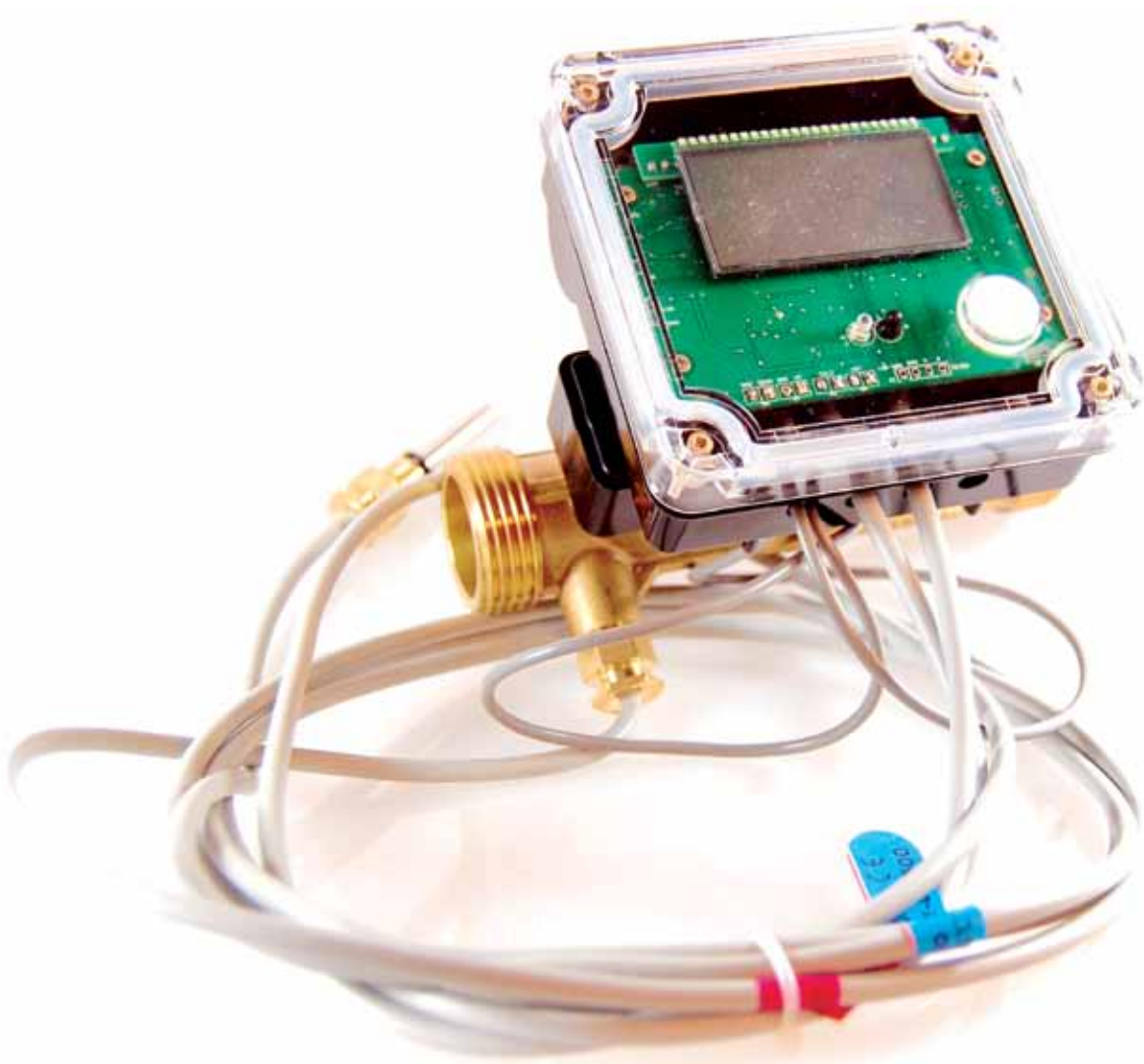
Using small increments of time to measure flow, liquid level and similar water and wastewater processing variables provides more accurate results and improves reliability over conventional mechanical methods. These include impellers, floats and other devices that can become clogged or corroded, causing malfunctions and inaccurate readings.

Time-to-digital converters (TDCs) use semiconductor technology to measure the change of a quantity over time in exceedingly small increments, with accuracy in the picosecond range. As a result, efficient, highly accurate and cost-effective solutions can be integrated into a single system-on-chip. There are many applications for TDC technology in water and wastewater processing.

Improved Flow Measurement

This technology is already being used in water meters where it replaces conventional mechanical impellers with ultrasonic elements. These elements send impulses that can be measured accurately to establish time differences and provide digital data. Over time, deposits can accumulate around and on impeller wheels, causing sluggish response, inaccuracy and possible failure. By contrast, TDC technology has no moving parts that can be affected by deposits, and it can be programmed to adjust for the inevitable buildup that occurs.

TDC sends out one ultrasonic pulse in the direction of fluid flow and a second against the flow. The flight time of the pulses between the transmitter and receiver is then measured electronically. A time difference proportional to the fluid's flow speed is generated, and TDC is used to measure the time of flight (TOF) of the ultrasonic pulse. Piezoelectric transducers generally are used as ultrasonic transmitters and receivers because they are well suited to both functions.



The same principles apply to measuring flow through pipe. Typically, TDC chips run at 3.3 volts, which provide enough signal strength to accommodate a 2-in.-diameter pipe. Larger-diameter pipe can be monitored simply by adding external signal amplification at higher voltages. This will provide a signal strong enough to drive the TDC transducers. The device manufacturer should be consulted to determine the exact specifications needed. The flow rate of wastewater and other dense fluids can be measured with the same technique, because there are no mechanisms to clog or restrict flow.

New integrated ultrasonic flow converters using TDC technology often incorporate analog front ends to simplify external circuits. In addition, these products now can track long-term changes in receive amplitude, which could indicate material buildup on the transducers and adjust for the changes automatically.

Better Level Sensing

For sensing the fluid level in a tank, TDC systems provide a robust, reliable and accurate solution. One method essentially sends an ultrasonic pulse that is reflected back from the surface of the liquid, with the time delay being measured by TDC. A similar approach uses radar pulses instead of ultrasonic bursts.

Another method uses magnetostrictive positioning, in which a magnetic float is positioned on a wire contained in a pipe. Microsecond electronic pulses are sent down the wire at regular intervals, creating a magnetic field around the wire. When they reach the magnet, at the level of the liquid, they create a shock interaction between the magnetic fields, which releases mechanical energy inside the wire. This energy propagates as an ultrasonic wave along the wire, where it is detected by an ultrasonic receiver. The time lag between the original current pulse and the reception is measured by TDC and converted to the fluid height. As a result of its high resolution, the TDC method provides more accurate results.

Although other electronic methods that employ microprocessors or digital signal processors can be used for tank level measurement, their reliability tends to be lower, especially at extreme temperatures or difficult environments. TDC chips have an operating range of -40°F to 125°F, which makes them well suited for outdoor applications in all climates.

Other Applications

Applications for TDC in other fields also can translate into process improvements for water and wastewater treatment. One example is measuring chemical dosage with high resolution and accuracy, even at extremely low flow rates. This technology already is used in medical and chemical applications but is not limited to the smaller

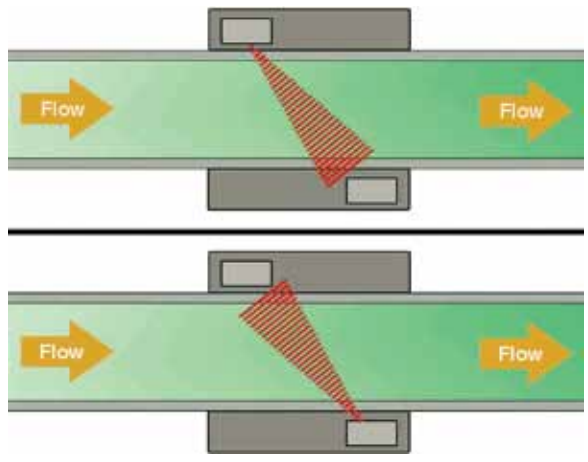
doses found in those fields. It also can measure larger quantities of liquids and gases as they are being injected during plant operations. TDC products that can measure zero flow and detect bubbles—both of which could be useful in some applications—are now available.

TDC technology also requires substantially less current. In an analog time-to-digital converter, the measured time difference is first converted into an analog voltage, which is then digitized by analog-to-digital conversion. While relatively high resolutions can be achieved with this method, it is subject to restrictions such as electronic "noise" and greater power consumption.

Digital TDCs can be divided into two groups: absolute delay time and relative delay time. The choice depends on the application, and some uses might benefit from a combination of both methods. Flow metering falls in the relative time delay group, both to achieve higher resolution and because one channel is usually all that is needed for flow measurement. The manufacturer should be consulted for assistance in applying the technology most effectively.

Absolute delay time TDC determines the number of inverter cycles in the measured time difference. Normally it would be used where the maximum number of channels and best pulse pair resolution are desired. For example, if an application might result in multiple hits on a particular channel a few nanoseconds apart, using absolute time delay would provide the best resolution between the pairs of pulses received on a channel. Chip design features make it possible to reconstruct the exact number of basic delay times.

Figure 1. Time of Flight Flowmeter



Resolutions in the area of 40 to 100 picoseconds can be achieved by a setup of the measuring core and use of the CMOS process.

Relative delay time TDC makes it possible to achieve higher resolutions than those imposed by the speed of the semiconductor process. This type of TDC achieves finer quantization by measuring a relative difference in delay time between two elements in the delay chain. By combining and offsetting the time differences between the pulses from multiple channels, it is possible to interpolate and achieve resolutions in the 10-picosecond range.

In electronic applications, TDCs provide the advantages of digital data without the need for analog circuits. They offer high resolution, which translates into greater accuracy, and they are adaptable to a wide range of measurement applications in water and wastewater processing. WWD

John Monteith is product manager for ACAM-USA. Monteith can be reached at john_monteith@acam-usa.com.

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