



Ultrasonic sensors: Now an even better choice for solid material level detection

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DSP, built-in temperature compensation, and new transducer materials have expanded the use of ultrasonics in solids measurements.

Noncontact ultrasonic instruments offer many advantages in measuring the levels of solid materials. They are easy to install and maintain, cost effective, and provide quick hassle-free level measurement via analog or digital interfaces. The only obstacle to their use seems to be the confusion some users have regarding when and where ultrasonic measurements are appropriate.

Thanks to advanced digital signal processing and other technological advances, today's ultrasonic devices can analyze individual data points to provide a reliable level measurement of most solid materials (including those that are very dry and dusty) even under dynamic conditions (Fig. 1).

Digital signal processing: What does it mean?

In the old days of analog signal processing, material level was determined by looking

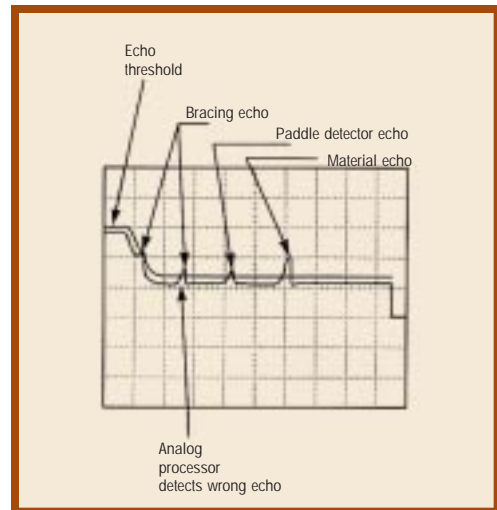


FIG. 2: With analog signal processing, the level was determined by looking for a return echo that was above a given threshold. The trouble was, if the first echo to cross the threshold was from built-in obstructions or a dynamic condition such as the fill stream, the instrument provided a false level indication.



FIG. 1: Thanks to advanced digital signal processing and other technological advances, ultrasonics are a sound choice to reliably measure dry, dusty materials such as cement and grains.

for a return echo that was above a given threshold. The first echo to cross the threshold was taken as the level measurement, without any other consideration. The trouble was, if the first echo to cross the threshold was from the fill stream or some other dynamic condition, the instrument provided a false level indication (Fig. 2).

Today, ultrasonic level measurement can provide the big picture. Digital signal processing (DSP) techniques applied to an ultrasonic receiver are making these devices smart enough to look at more than just the first return echo when making a level measurement decision. With DSP technology, the

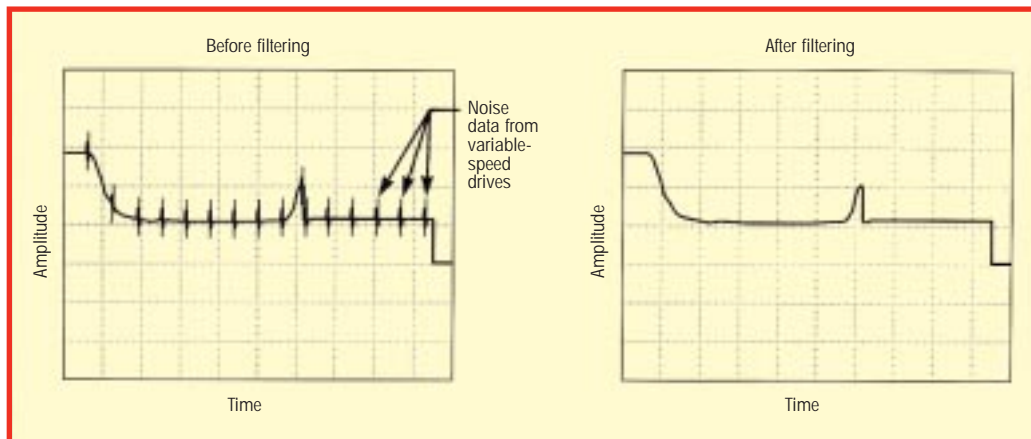


FIG. 3: Digital filtering is one method of mathematically manipulating the stored echo profile to remove unwanted data—such as electrical noise generated by variable-speed drives.

instrument is capable of taking a snap shot of the level conditions in a vessel and recording it in memory in a graphical format called an echo profile. Once an echo profile is captured in memory, the instrument can manipulate the data in ways that *clean it up* and make the level measurement decision more reliable.

Digital filtering is one method of mathematically manipulating the stored echo profile to remove unwanted data such as electrical noise (which, as you know, is always present in an industrial environment). For instance, variable-speed drives operating nearby equipment can produce electrical noise that is usually of very high amplitude, yet very short duration compared with other data in the echo profile. Because digital filtering can remove data of less than a designated duration, the noise can be removed without affecting the echo profile (Fig. 3). For applications with random interference sources, such as high dust or noise levels, digital filtering can average many echo profiles and form a composite that averages out the interference to more accurately determine the material level.

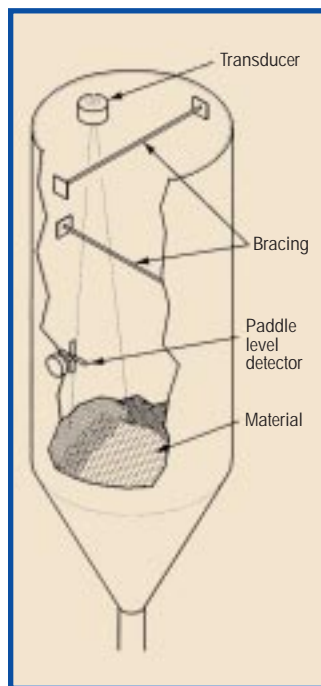


FIG. 4: There are almost always obstructions of one kind or another in any solids application that must be dealt with—whether its bracing, ledges, ladders, or lumps.

Why do I need it for solids applications? Measuring solid materials is by far the most demanding application for digital signal processing as applied to ultrasonic technology. Unlike liquid measurement, the material does not lie flat, is not particularly reflective, is almost always obscured by thick clouds of dust, and invariably makes an incredible amount noise as it falls, drops, or is blown into the vessel.

There are almost always obstructions of one kind or another in solids applications that must be dealt with—whether its bracing, ledges, ladders, or lumps (Fig. 4). A lump of material sticking to the side wall of a vessel can result in an indication that the vessel is half full

when it's really just about empty. As you can imagine, operators and production managers tend to get a little upset when they don't have enough material to finish a job.

As if obstructions weren't challenging enough, solid materials also are typically fed into a vessel from the top, making it difficult to avoid the fill stream when choosing a mounting location for the ultrasonic transducer. The most common error is to install a transducer either in the fill stream, or to have its view of the vessel obscured by the fill stream. So, what's needed is an instrument that is smart enough to know the difference between the fill stream and the actual level.

Filtering techniques: How to deal with some real-world problems

One of the easiest and most powerful filtering techniques used is multiple profile averaging. Consider the dynamics inside a vessel during a fill cycle: tons of material and dust, lots of noise, and swirling air currents. Consider further that most of the activity is random in nature, with randomness being a critical factor. This is because if any list of random positive and negative numbers is averaged, the result is zero.

In this same fashion, an echo profile can be averaged with another profile that is taken at nearly the same moment in time. The echo profile is stored in memory as a string of numbers that can be averaged with each other to obtain an average echo profile. All of the data that tends to be stable over the time frame of the measurements remains when successive profiles are averaged together. The result is a composite profile that only contains those items that are in the same place for each mea-



surement. Because the material level is always in the same place (given the short time frame of the level profiles), the echo from the material level is enhanced while the random movements of dust and air are filtered out. Remember that each profile is taken within a few milliseconds of the others. So from the operators point of view, all of the measurements seem to take place simultaneously.

Statistics come to the rescue

Statistical filtering techniques are one of the most powerful ways to improve the operation of a noncontacting level measurement device. For example, if a tank has an agitator inside, the agitator blades must be ignored when they are above the level of material in the tank. In this case, a simple statistical filter allows the instrument to read the actual level below the agitator without producing a false high-level signal.

Here's how this type of filter works. As the agitator rotates in the tank, it occasionally comes into the view of the instrument. However, when the agitator filter is turned on, the instrument looks for level measurements that occur in the same place several times in a row. The filter is programmed so that the instrument will only indicate a level change if multiple measurements in a row occur in the same place. If the agitator blade comes into view during operation, it will only be in view for a limited number of measurements. Therefore, the agitator is ignored and the true level is continuously tracked.

A similar type of filter is used in solid material applications to improve the stability of the signal under extreme conditions. For example, during heavy filling conditions the fill stream may occasionally move into view of the instrument and cause a false high-level indication. The same type of filter used to ignore an agitator can be used, in this case, to ignore the false high measurements caused by heavy dust and fill-stream interference.

Dealing with dust and noise

Heavy dust accumulation attenuates the signal of an ultrasonic transmitter. In most cases, the attenuation is caused by diffraction when the dust particles break up the ultrasonic wave as it travels down through the dust.

There are a number of ways to avoid this

attenuation problem. For example, if an application is expected to have heavy dust under filling conditions, the power output of the transducer used to make the measurement becomes an important selection consideration. In some cases, just improving the power output is enough to overcome the detrimental effect of the dust.

In more severe cases, other techniques are used. For example, lower frequencies propagate further through dusty environments than high frequencies. Therefore, in certain cases, you may want to use long-range transducers, since they usually operate at lower frequencies. Sometimes, very-long-range transducers operate at frequencies low enough for humans to hear—which means that the measurement is really sonic rather than ultrasonic.

Transducer designs

Ultrasonic transducers have seen a number of design changes in the years since they were first used to measure solid materials. One of the most significant changes has been the incorporation of an ambient air temperature sensor in the body of the transducer. Now that most transducers have temperature compensation built in, there's no need to use separate sensors. And because the sensor is part of the transducer circuitry, most transceivers can read the temperature sensor over the same pair of wires they use to operate the transducer. Built-in temperature compensation improves the accuracy of the system and reduces installation cost.

Chemical compatibility is an important consideration when choosing any level measurement technology. The material used for the transducer is an important factor when using ultrasonics to measure solid materials. Transducers are now available in a variety of materials, including Teflon™, Tefzel™, Kynar™, Kynar Flex™, CPVC, Hypalon™, and stainless steel. Chemical compatibility issues are usually handled by choosing a transducer made of a material known to be compatible with the material being measured (*Fig. 5*).

If you are unsure about material suitability, contact the manufacturer of the transducer, or use a chemical compatibility chart published by the manufacturer of the transducer material. There are also a number of sources



FIG. 5: Ultrasonic transducers, such as this Echomax series from Milltronics, can be designed to withstand high temperatures, hot corrosives, and harsh chemicals.

of chemical compatibility information available on the Internet.

Give buildup the brush-off

Most solid applications are dusty. In areas where dust is extremely heavy, keeping the transducer clean can be a critical factor. If material were

to build up on the face of the transducer, it would reduce its ability to transmit and receive. One way to help a transducer keep itself clean is to generate a repetitive, pulsating displacement at its face.

Construction materials also can play a role in keeping a transducer's face free of buildup. By using materials with good release characteristics and designing powerful transducers with pulsating displacement at its face, buildup never gets started.

Handling the heat

In the past, high temperatures were a limiting factor when using ultrasonic instruments in some solids applications. Until about five years ago, the high temperature limit of a transducer was around 200°F—which isn't a particularly limiting factor for most solids applications. However, in areas where the material is coming from a hot process like a kiln or drier, a transducer could suffer considerable damage if exposed to the high process temperatures.

Today's improved designs have extended the maximum temperature range of many transducers to around 300°F. Although an

extra 100° may not sound like a significant jump, remember that the ultrasonic transducer does not come in direct contact with the process material. In a majority of the applications, the extra 100°F is just what it takes to get the job done.

Remaining stable while turning up the heat

Ultrasonic transducers also need to work reliably over the large temperature swings that are common in many operations. This capability is one of the most impressive design breakthroughs for ultrasonic transducers. The same new designs that allow ultrasonic transducers to operate up to 300°F also allow them to remain extremely stable over their operating range.

Ultrasonic level measurement is an excellent choice for many solid-material measurement applications. The installations and startups are getting easier every day, and many of the factors that eliminated the use of ultrasonics in the past have been eliminated as a result of advancements in technology. █

About the author

Doug Duncan is product manager, ultrasonic level products, for Milltronics, Inc. He has previous experience in applications and field engineering as well as marketing management. Duncan holds a BSEE from Oklahoma State University.

For more information...

The author, Doug Duncan, will be available to answer any questions you may have about this article. He can be reached at (817) 548-2096 during normal business hours.