The Pursuit of Accurate and Reliable Vibration Sensing For Condition-Based Predictive Maintenance

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IDEA IN BRIEF

Explore the benefits and limitations of piezo-based sensors and handheld data collection tools when used for condition-based predictive maintenance as well as the advantages of fully integrated and reliable vibration sensors.

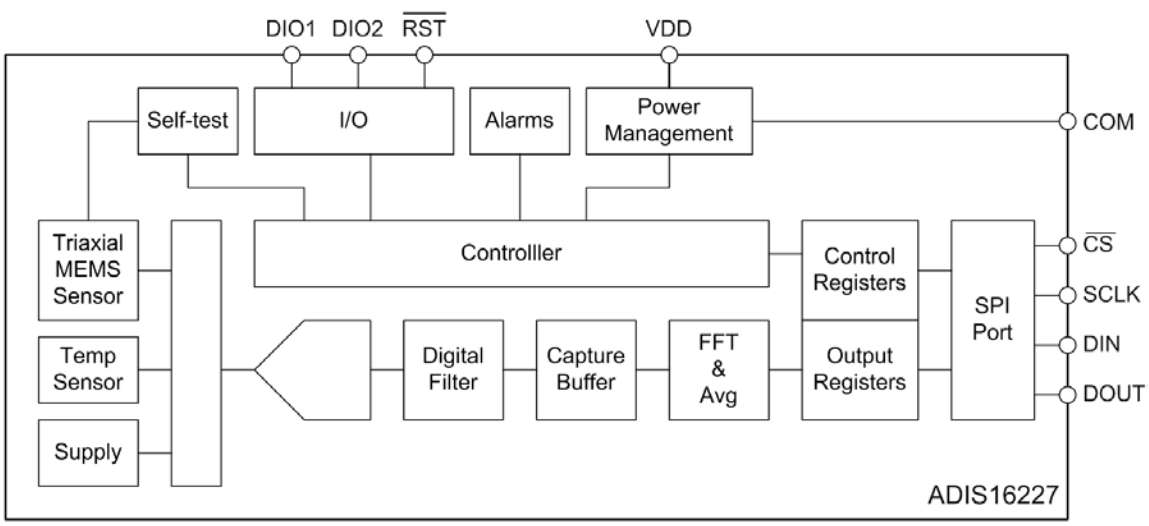
Precision industrial processes are increasingly reliant on efficient and consistent operation of motors and associated machinery. Imbalance, defects, loose fittings, and other anomalies in the machinery typically translate into vibration, and then loss of precision, as well as safety concerns. If left unaddressed, besides the performance and safety issues, loss of productivity becomes inevitable if equipment needs to be taken off-line for repair.

Condition-based predictive maintenance is a known and proven approach for avoiding productivity loss, but the value of this approach is matched by its complexity. Existing methods have limitations, particularly when it comes to analyzing the vibration data, however collected, and isolating error sources.

Existing data collection approaches include simple piezo-based sensors mounted to the machinery and handheld data collection tools. These methods have a number of limitations, particularly when compared with the ideal solution of a complete detection and analysis system which can be embedded on or in the machinery and act autonomously. These limitations, and comparisons with the ideal, are explored further in this article.

REPEATABILITY OF MEASUREMENT

Handheld vibration probes offer some implementation advantages such as not requiring any modification to the end-equipment, and the fact that they are relatively highly integrated, given their large (brick) size, allows sufficient processing and storage. However, a major limitation is the repeatability of the measurements. Slight differences in the probe location or angle will produce inconsistent vibration profiles, making time comparisons inaccurate. Thus, the maintenance technician is left with the question of whether any observed vibration shift is due to an actual change within the machinery, or just a change in the measurement technique. Ideally, the sensor would be both compact and integrated sufficiently to allow direct and permanent embedding within the equipment of interest.



SCHEDULING OF MEASUREMENT

Another limitation of the handheld probe approach is the lack of real-time notification of troublesome vibration shifts. The same is true for most piezo-based sensors which are typically at a very low level of integration (transducer only in some cases), with the data transferred elsewhere for later analysis. These devices require external intervention and, thus, present an opportunity for missed events/shifts. On the other hand, an autonomous sensor processing system which includes sensor, analysis, storage, and alarm capability, and is still small enough for embedding, offers the fastest notification of vibration shifts, as well as the best ability to show time-based trends.

UNDERSTANDING THE DATA

The ideal of real-time notification from an embedded sensor (discussed previously) is only possible if frequency domain analysis is employed. Any given equipment typically has multiple sources of vibration such as bearing defects, imbalance, and gear mesh, plus by-design sources such as a drill or machine press producing vibration in its normal course of operation. A time-based analysis of the equipment produces a complex waveform, combining these multiple sources, which provides little discernible information prior to FFT analysis. Most piezo-based sensor solutions rely on external computation and analysis of the FFT. This not only eliminates the possibility of real-time notification, but it also puts substantial additional design burden on the equipment developer. With embedded FFT analysis at the sensor, vibration shifts can be isolated to specific sources immediately. Such a fully integrated sensor element could also reduce development time for equipment designers by 6 to 12 months, given the completeness and simplicity of a fully integrated and autonomous sensor.

ACCESSING THE DATA

Embedded FFT analysis assumes that the analog sensor data has been conditioned and converted to digital, and thus data transmission is greatly simplified. In fact, most vibration sensor solutions in use today are analog output only, leading to signal degradation during transmission, not to mention the already discussed complexity of off-line data analysis. Given that most industrial equipment requiring vibration monitoring tends to exist in noisy, moving, inaccessible, even dangerous environments, there is a strong desire to not only reduce the complexity of interface cabling, but also perform as much of the data analysis as possible at-the-source to capture the most accurate representation of the equipment vibration as possible.

HOW MUCH DATA

Many existing sensor solutions are single axis piezo transducers. These piezo sensors provide no directionality information, and thus limit the understanding of the equipment vibration profile. The lack of directionality translates to the need for very low noise sensors, which also impacts cost. The availability of triaxis MEMS-based sensors, if precision aligned across each axis, allows a significant increase in the ability to isolate the vibration source, while potentially improving cost.

PROBE POINTS

The question of where to place sensors is critical, but highly dependent on the type of equipment, environment, and even the life cycle of the equipment. With existing high cost sensor elements limiting the number of probe points to a few or one, placement is more critical. This translates to either significant additional up-front development time to determine optimal placement through experimentation, or in most cases leads to some compromise in the amount and quality of the data to be captured. The existence of more fully integrated sensor probes at a fraction of existing costs can allow placement of multiple probes per system and less up-front development time/cost or simply fewer and less costly sensors.

EQUIPMENT LIFE-CYCLE SHIFTS

The transducer element, regardless of technology, is an important consideration, but typically more critical is the sensor signal conditioning and processing wrapped around the transducer. The signal conditioning and processing is not only specific to the unique equipment, but also to the life-cycle of the equipment. This translates to several important considerations in the design of the sensor. Earlier analog-to-digital conversion (that is, at the sensor head, vs. off-equipment) allows for configuration/tuning in-system. The ideal sensor would provide a simple programmable interface that would simplify the equipment set-up, through quick baseline data captures, manipulation of filtering, programming of alarms, and experimentation with different sensor locations. With existing simple sensors, to the extent they are configurable at equipment set-up, some compromise in sensor settings still must be made to accommodate changes in maintenance concerns over the life of the equipment. For example, should the sensor be configured for early life when equipment faults are less likely, or end-of-life when faults are not only likely but potentially more detrimental? The preferred approach is an in-system programmable sensor which allows configurability to changes in the life cycle. For instance, infrequent monitoring for the lowest power consumption during early life; followed by reconfiguration to frequent (user programmed period) monitoring once a shift (warning threshold) has been observed; in addition to the continuous monitoring for and interrupt-driven notification of user-programmed alarm thresholds.

IDENTIFYING SHIFTS/TRENDS

The previous discussion on adapting the sensor to changes in equipment life cycle is somewhat dependent on knowledge of a baseline equipment response. Even simple analog sensors can allow this, assuming the operator takes measurements, does the off-line analysis, and stores this data off-line with proper tagging to the specific equipment and probe location. A preferred and less error prone approach would allow baseline FFT storage at the sensor head, thus eliminating any potential for misplaced data. The baseline data also helps with establishing alarm levels which again would ideally be programmed directly at the sensor, and thus in any subsequent data analysis/capture where warning or fault conditions are detected, a real-time interrupt can be generated.

DOCUMENTATION/TRACEABILITY

Within a factory setting, a proper vibration analysis program may be monitoring tens or even hundreds of locations, whether by handheld probe or embedded sensor. Over the course of a given piece of equipments lifetime, this may produce the need for capturing thousands of records. The integrity of the predictive maintenance program depends on the proper mapping to the location and time of the sensor collection point. For lowest risk, and the most valuable data, the sensor should have a unique serial number and the ability to time-stamp the data, in addition to embedded storage.

RELIABILITY

The previous discussion highlights methods to improve existing sensor-based approaches to vibration monitoring for predictive maintenance. However, what if the sensor becomes faulty (performance shift), rather than the equipment? Or, if operating with a fully autonomous sensor (as described as the ideal), how confident can we be that the sensor continues to work at all? With many existing transducers, such as piezo-based, these situations present a serious limitation because simple piezo sensors have no means of providing an in-system self-test. There is always a lack of confidence in the consistency of data recorded over time, and in the end-of-life critical monitoring phase where real-time fault notification is time and cost critical and can be a significant safety concern, there is always a concern that the sensor could become non-functional. An essential requirement of a high confidence predictive maintenance program is the ability to remotely self-test the transducer. Fortunately, this is possible with some MEMS-based sensors. An embedded digital self-test capability will close the final gap on a reliable vibration monitoring system.

Analog Devices' ADIS16227 is one example of a fully autonomous frequency domain vibration monitor capable of addressing all ten of the critical concerns discussed previously. The ADIS16227 features embedded frequency domain processing, a 512-point real value FFT, and on-board storage providing the ability to identify and classify individual sources of vibration, monitor their changes over time, and react to programmable threshold levels. The device provides configurable spectral alarm bands and windowing options allowing analysis of the full frequency spectrum via the configuration of 6 bands, Alarm 1 (warning threshold), and Alarm 2 (fault threshold) for earlier and more accurate detection of problems. At its core is a triaxis wide-bandwidth (22 kHz resonance) MEMS-based sensor with configurable sample rate (up to 100 kHz) and averaging/decimation options allowing a more accurate assessment of even subtle vibration profile changes. The MEMS sensor provides a digital self-test mode to provide continuous confidence in functionality and data integrity. Its compact 15 mm cube configuration is fully embedded and programmable and enables placement close to the vibration source and early detection of small signals in a repeatable way. This avoids data discrepancies due to differences in location/coupling from measurement-to-measurement using handheld devices.

The introduction of fully integrated and reliable vibration sensors, with the ability for autonomous and configurable operation, provide predictive maintenance program developers the ability to significantly improve the quality and integrity of the data collection process, without the limitations and compromises posed by past vibration analysis approaches. With the high level of integration and a simplified programmable interface, these new sensors enable easier adoption of vibration sensing, previously limited to a handful of highly skilled technologists with decades of analytical experience in machine vibration.

RESOURCES

For more information, visit www.analog.com.

Products Mentioned in This Article

Product	Description
ADIS16227	Digital Triaxial Vibration Sensor with FFT Analysis and Storage

One Technology Way • P.O. Box 9106 • Norwood, MA 02062-9106, U.S.A.
Tel: 781.329.4700 • Fax: 781.461.3113 • www.analog.com