# Machine Shock & Vibration Testing

*using the WaveBook*

*Machine Design*

**Application Note #63**

## Application Summary

Sensitive instruments and machines such as integrated circuit wafer scanners often contain motion systems that control displacements of one micron or less. This dynamic makes the machines particularly sensitive to even minute environmental vibrations, so it's essential that the equipment contains high stiffness support frames to handle all incidental shock and vibration. Mecal, located in Enschede, Netherlands, is one company that specializes in designing and manufacturing such machine support frames.

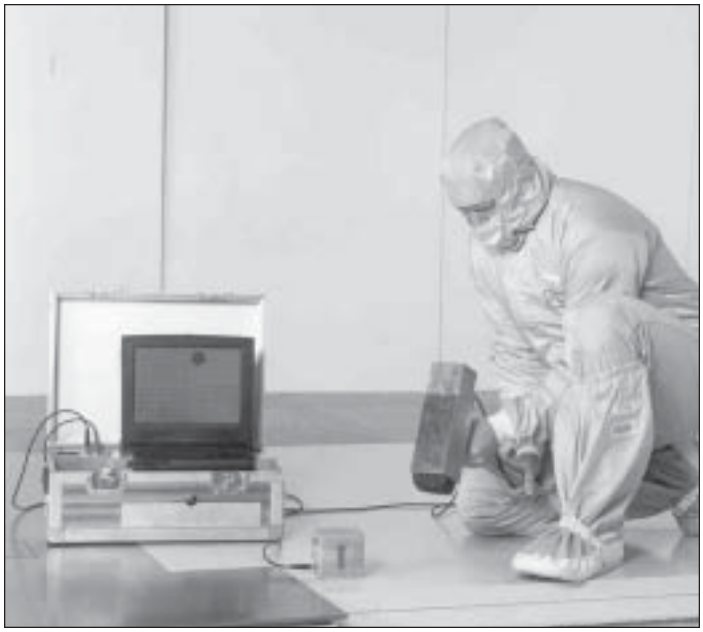
Originally, Mecal began as a consultancy, providing custom design services and specializing in finite element analysis. The business eventually expanded to include the Pantheon Group that designs, manufactures, and installs custom machine bases. This was a natural product outgrowth for Mecal because of its expertise in supplying a variety of bases with optimum stiffness and its vast experience in FE techniques. In order to ensure the proper stiffness for a particular application, the bases are made with a unique combination of materials and design techniques. During the design activity, simulation and analysis software characterize the machine frame, and later, physical models are built and tested to verify the calculations. The requirement for accurately measuring a frame's stiffness includes a data acquisition system that can record and analyze the response with an impact hammer and accelerometer test.

## Possible Solution

Wim Fabricius, Mechanical Engineer at Mecal's Pantheon division, has performed numerous shock and vibration tests over several years to verify machine frame stiffness using a variety of well-known instruments. Until recently, he typically rented the equipment on an as-needed basis, principally because it was too expensive to justify purchasing. But the instruments had a few limitations including too few channels, difficulty in operating, insufficient accuracy, and excessively large size and weight. Furthermore, the equipment ran on proprietary software and was just too complex for field use, not easy enough for the installation team to operate. What's worse, the instruments were not convenient or easy to pack up and load on a plane when Fabricius had to conduct tests at a customer site or at another Mecal location. The engineering group needed to upgrade to a laptop computer-size unit and write their own software programs.

## IOtech's Solution

Fabricius investigated alternative solutions for his data acquisition needs. He found more accuracy, smaller size, and lighter weight first in the IOtech DaqBook® and later, in the WaveBook™. Moreover, their price fit his budget so he purchased the two systems for Mecal instead of renting. Both units met the requirements of laptop computer size, weight, and programmability. Says Fabricius, "What I like best is that the software is very easy to program and



*Test engineers mount a single-axis accelerometer on a machine support base and strike its surface with a specially instrumented hammer to produce vibrations. The accelerometer senses the vibrations on the support base and passes them to the IOtech WaveBook where they are recorded and managed with the DASYLab software. The finite element model graphic illustrates the vibration mode patterns of a floor of a semiconductor manufacturing facility on which a custom made machine support frame will be installed.*

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has never failed us. I think the major reasons we chose the IOtech equipment was the DASYLab® software and ICP® compatibility. We always use piezoelectric sensors, so we need equipment that is compatible and has built-in signal conditioning. With DASYLab software, we can build our own programs, so to speak, and now that we know the program, we can find almost any property we need to measure." For vibration measurements, Fabricius uses triaxial accelerometers, but only one axis of the accelerometer at a time for the impact-hammer test.

The performance of support frames depends on their stiffness measured in Newtons/meter, weight, the geometric design, and the materials of construction. The stiffness, also known as rigidity, cannot be too high or the vibrations will not damp out quickly enough. On the other hand, they must be stiff enough to prevent transmitting motion caused by either external sources or the machine itself. Over time and numerous tests, Mecal has found concrete to be an optimum material for most applications. The concrete is not too heavy, and when properly coated, the support frames are compliant with clean-room specifications. But the frame is not a simple concrete block design. FE analyses performed on virtual models, backed by dynamic testing using the WaveBook and DASYLab software, ensure the optimum shape and stiffness. "Besides verifying our own products, we also act as a consulting company, providing all types of services concerning vibration issues. We have recently started up a division within the Pantheon Group, called Dynamic Services, that uses the IOtech equipment as a successful tool to provide valuable advice to our semiconductor manufacturing customers," adds Fabricius.

The WaveBook's measurement speed is more than adequate for the job. It doesn't need to measure very high frequencies, just typically the range of 1.0 to 1,000 Hz. The WaveBook samples in the MHz range, so it has more than enough margin. Measurements are known to be accurate from 1.0 Hz upward because Fabricius uses digital filtering below that frequency and high-pass filtering below 0.1 Hz to suppress the very low frequency sensor noise. Furthermore, no problems have been observed with the 50/60 Hz power supply frequencies that often contaminate data, even though a spike might pop up at 50 or 60 Hz when running big equipment. Of primary concern is measuring frequency response and resonant frequencies, but the FFT and coherence modules in DASYLab, along with numerous integrators and differentiators are often used.

"The WaveBook is very durable, and durability is critically important for us," says Fabricius. "We bring the equipment with us on a plane, but it always goes in the baggage compartment with other heavy suitcases, not with the hand-carried luggage. So it must withstand the abuse of the other, much larger and heavier baggage."

## Conclusion

Fabricius currently uses accelerometers exclusively, but he may try to measure sound pressure in the future. "I expect it will be very easy with the WaveBook. I will just connect a microphone and record the data," says Fabricius. "We are trying to expand our measurement capabilities so we can service other divisions. For example, we are also running calculations on wind turbines and gears, and in the future, we will back up the designs with actual test measurements using the WaveBook and DaqBook. But we are just in the start-up phase right now."

## WaveBook Series

The WaveBook™ series of portable and desktop digitizers offer multi-channel waveform acquisition and analysis for portable or laboratory applications. All WaveBook models include 8 built-in channels expandable up to 72 channels of voltage, accelerometer, microphone, strain gage, thermocouple, position encoder, frequency, high voltage, and other signal types. For applications beyond 72 channels, up to four WaveBooks can be combined within one measurement system, for a total capacity of 288 channels. WaveBooks are available with either an Ethernet or parallel connection to a PC.

### Features

- PC connection via Ethernet, parallel, PC-Card, or PCI card
- 1 µs/channel scanning of any combination of channels
- Expandable up to 288 high-speed channels
- SYNC connection allows multiple units to measure synchronously
- Add up to 224 lower-speed thermocouple channels
- DSP-based design provides real-time digital calibration on all channels
- Single and multichannel analog triggering with programmable level and slope
- Digital TTL-level and pattern triggering
- Pulse trigger and external clock
- Programmable pre- and post-trigger sampling rates
- Sixteen 1-MHz digital inputs
- Operable from AC line, a 10 to 30 VDC source, such as a car battery, or optional compact rechargeable battery module

### Included Software

- WaveView™ for *Out-of-the-Box*™ setup, acquisition, and real-time display
- eZ-Analyst™ for real-time spectrum analysis
- Export data in third-party formats
- Includes drivers for Visual Basic®, Delphi™, C++ for Windows®; DASYLab®, and LabVIEW®
- ActiveX/COM development tools