REALTIME
Update
Hewlett-Packard Summer 1995

A Newsletter for Noise, Vibration and Electromechanical Test Professionals

VXI-based system captures real data for virtual-reality simulators

Brad Terrell, Symmetrix

As a world leader in training commercial aircraft pilots, FlightSafety International is a major developer of virtual-reality flight simulators. These simulators are so realistic that the FAA allows pilots who have flown in them to obtain certification without ever having been in the real aircraft. To program a simulator of this quality, FlightSafety needs to capture many characteristics of actual aircraft in-flight with great precision and dependability.

FlightSafety asked us to develop an acquisition and measurement system that they could count on to collect these critical data points in a variety of aircraft, from small corporate jets to commercial airliners. The system also needed to be compact enough

Also in this issue:

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to fit in small jets with limited space for test equipment. Low power consumption was key too, since the system operates from the aircraft's batteries.

We found the right solution in VXI, the industry-standard open system architecture for test and measurement. By combining off-the-shelf hardware with custom software, we met the multiple challenges that the FlightSafety application presented.

Real-time operation for cost-effective data capture

With flight time costing between $2000 and $6000 per hour, we needed a system that was fast enough to allow in-flight signal monitoring and flexible enough to change channel allocation, add parameters or change sampling rates "on the fly." This means using a real-time operating system. For maximum efficiency, we adopted a client/server software architecture, with the VXI-based computer as the server and the flight engineer's laptop computer as the client (see figure 1).

In the past, data capture for the flight simulators was very expensive. Older systems used cumbersome 12-bit external A/D converters that required hours of post-capture error analysis and correction. And since these systems did not permit in-flight monitoring, a single problem with the captured data might require an expensive repeat of the test flight.

Controlling data acquisition

The heart of the system is the HP RADI-EPC7 controller, a 486 PC module popular in VXI systems. All data acquisition is controlled by a program that takes advantage of the Lynx operating system's real-time capabilities (Lynx is a real-time variety of UNIX®). This core acquisition program retrieves data from each VXI instrument at precise, time-stamped intervals. This is absolutely necessary to preserve time relationships between signals. For example, raising the aircraft's flaps is followed by a corresponding change in altitude. To recreate this event accurately with a flight simulator, we need to record the precise magnitude of the altitude change and exactly when it began after the pilot raised the flap.

A real-time operating system is essential for those VXI instruments that do not have internal data buffers. And for those instruments that do (such as the HP E1413B A/D converter), we can match the buffer "fill rate" of each channel to the sample rate appropriate for that transducer. This permits a buffer to fill at the same rate as new data is acquired. Therefore, when data is retrieved, an entire buffer's worth of data is captured.

Another reason for adjustable, independent sampling rates for each signal is to minimize disk space. This is an important consideration with test flights that can take up to six hours.

Gathering the data

A typical test flight can involve hundreds of parameters to measure, with bandwidths ranging from less than one Hertz to several hundred

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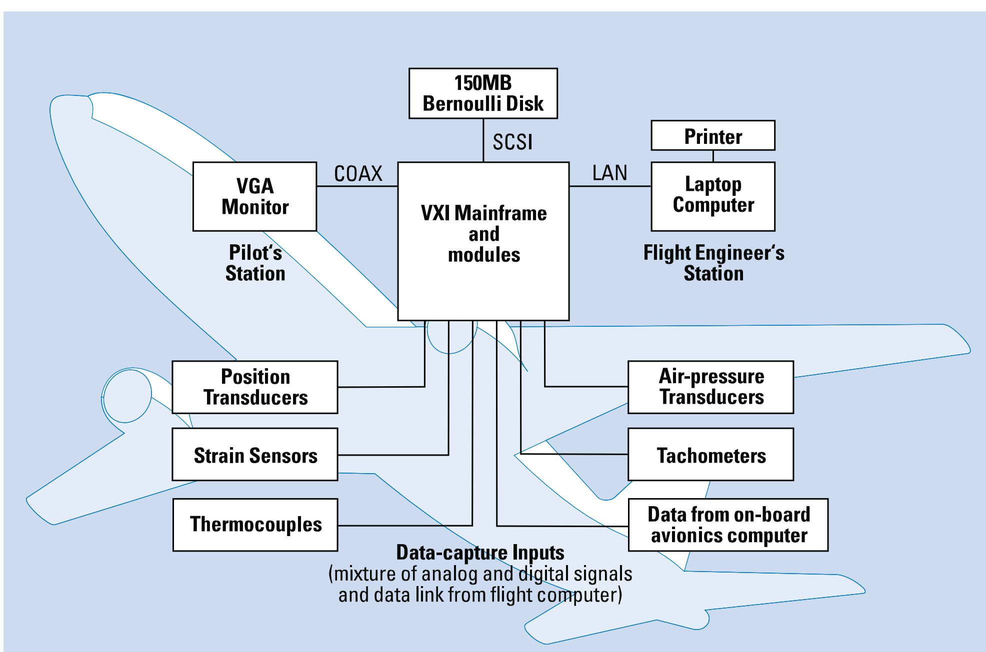

Figure 1
The FlightSafety data collection system uses a VXI controller and a laptop computer in a client/server architecture.

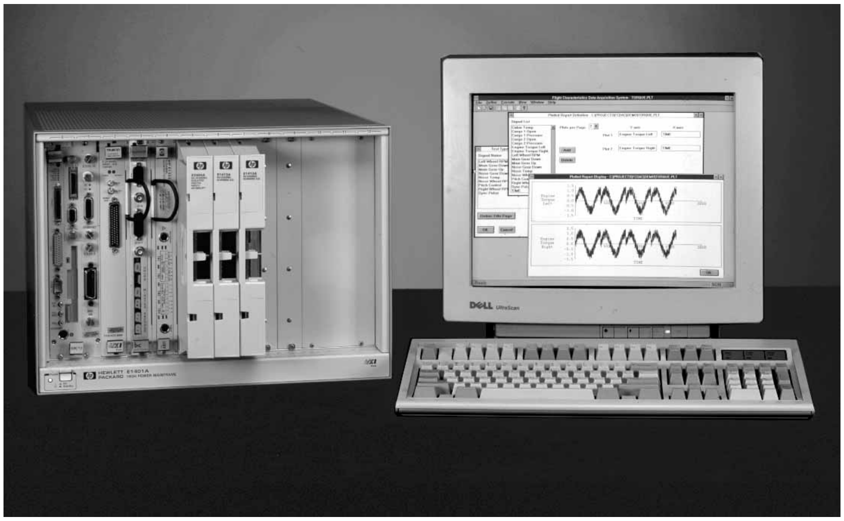

Figure 2
The VXI portion of the data collection system

Hertz. In addition to analog transducers, there are many other signals to monitor, ranging from simple switch closures to complex navigational information from the aircraft's on-board avionics computer. Using primarily Hewlett-Packard VXI hardware, we were able to configure a complete system with off-the-shelf components (see Figure 2).

- For analog signals, the system uses two 64-channel HP E1413B A/D converter modules. These provide up to 128 channels with enough flexibility to accommodate position transducers, strain sensors, thermocouples and air pressure transducers (linearization is built into the software to compensate for transducer effects).

- For digital signals, the system uses a single HP Z2404A digital input module. Typical signals monitored include landing gear status, stall warning on, and auto-pilot engaged. Timing is particularly important for digital events, since some events occur only a millisecond apart.

- To track parameters such as fuel consumption and movement of the aircraft relative to runway transponders, the system incorporates two HP E1332A 4-channel counter/totalizer modules.

- For engine, propeller and wheel speed, we use HP CENC-TAC8 4-channel tachometer modules.

- Engine torque is picked up with a third-party synchro/resolver module.

- To record the exact location of the aircraft as well as other parameters from the on-board avionics computer, the system uses an HP TASC-429 module.

- An HP BANC-350 module provides the industry-standard IRIG-B timecode, which allows for post-capture synchronization between system data and a separate in-flight video recorder.

Reaping the benefits of client/server

The client/server architecture provides fast data capture, easy system control and useful monitoring features. The PC client program communicates to the VXI-based server via a LAN. The flight engineer uses the client program to control the entire data-collection procedure, define all data-collection parameters and to display measured data (and print it, if necessary) during the flight.

The server program controls the VXI instruments and generates a real-time X-Windows display for the pilot. Because the pilot's display resembles the aircraft's own instrumentation, the pilot can use the server display to verify that the plane is "in trim" before executing a flight test maneuver. (Interestingly enough, we've discovered that the transducers installed for the data acquisition system are often more accurate than the standard aircraft instrumentation.)

VXI is ready

The ability to mix and match hardware and software components in VXI gives system designers and integrators much more solution flexibility than we had with older technologies. Aside from successfully meeting FlightSafety's demanding data collection challenge, this system demonstrated that VXI is ready to solve demanding real-world, real-time problems. ■

For more information about this system, contact Brad Terrell or Paul Hiller at Symmetrix in Austin, Texas, at (800) 560-TEST or (512) 328-7799.

Using psycho-acoustic analysis to characterize product noise

by Josef Hobelsberger, Mueller BBM
and Al Prosuk, m+p international

It's been said that the 20th century is not simply the age of industry, but the age of noise. No matter where we work, where we live, or what we do, noise surrounds us. Increasingly, product manufacturers must measure, quantify and analyze acoustic noise of their products to better meet noise standards and remain competitive in today's marketplace.

It makes no difference if you're designing automobiles, office products, or industrial machines. Your challenge today isn't simply to make a better mousetrap—it's to build one that's also quieter.

Basic sound measurements

Product noise characterization is based on two essential measurements—*sound power* and *sound pressure*.

Sound pressure is how we hear. It's the movement of our eardrums in response to tiny changes in atmospheric pressure as sound reaches our ears. Sound pressure is a measure of sound only at one point in space because it varies with the distance from the source (and it diminishes by the square of the distance as we move away from the source).

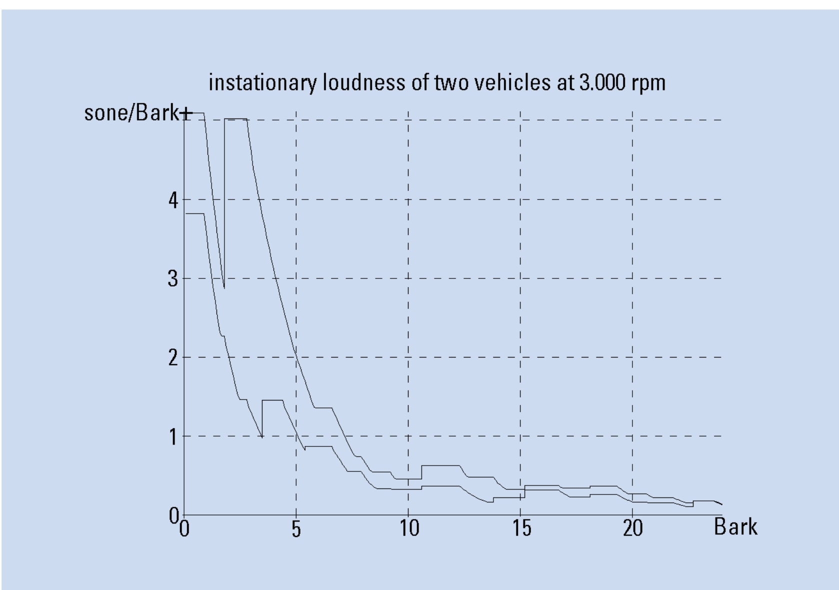

Figure 1
Comparing instationary loudness of two vehicles at 3,000 RPM.

Sound pressure is easy to measure. Portable sound-level meters have been around for many years and while useful, they don't provide enough information for product development. Sound-level meters indicate "how loud" noise is, but they don't reveal any frequency information—a sound-level meter is essentially a voltmeter that responds over the entire range of human hearing. Spectral analysis of sound requires an octave analyzer or a spectrum analyzer (some instruments can do both, using FFT-based DSP technology).

Sound power is the only true measure of a product's noise output. For many years, the only way to measure how much noise a device made was to bring it into a completely "dead" room (an anechoic chamber) and take a series of averaged sound pressure readings to estimate sound intensity from the device. This technique works well but has many limitations. For one thing, the device-under-test has to be small enough to fit into the anechoic chamber. Also, there aren't many anechoic chambers (they're costly to build), so test time is normally very expensive.

Within the last 20 years, sound-power measurements without using anechoic chambers have come into use with the development of sound-intensity techniques. These use a special two-microphone probe that uses both phase and magnitude information to minimize the influence of reflected or external sounds.

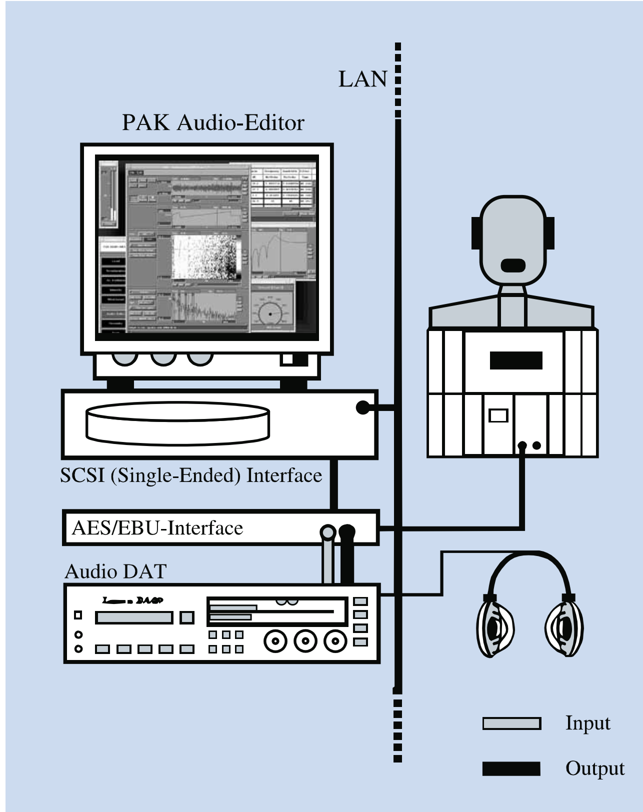

Figure 2
The PAK 2-Channel Audio Data Analysis System is based on the Hewlett-Packard Series 9000 workstation and a digital audio tape recorder.

Additionally, sound-intensity measurements are used to locate the source of specific noise components, making them extremely useful when troubleshooting noise problems for large, complex machines.

Limitations of simple sound measurements

Because tests in anechoic chambers were so expensive, for many years simple sound-level tests (using portable meters) were the only noise measurements generally made. While helpful, these measurements didn't reveal enough information to quantify how people reacted to a particular noise signature. Some noises, while seemingly low-level when measured with sound-level meters, were actually much more annoying to people than other noises that measured louder.

Early on, researchers recognized the limitations of simple sound-level meters and did attempt to gather frequency information as well. By the late 1940s, rudimentary 1/1- and 1/3-octave analyzers were available. For the first time, acoustic consultants and design engineers could measure noise and characterize predominant noise components. Within the next two decades, noise analysis (in one form or another) became commonplace as engineers used it to design quieter buildings and products—quieter factories, ventilation systems, machine tools, airplanes, automobiles, trains, buses, communications systems—practically every conceivable product or process.

We don't hear noise the same way we measure it

Much of what we know about how the human ear responds to sound was done by telephone engineers (notably Fletcher and Munson at Bell Telephone Laboratories in the United States, and by Barkhausen in Germany). During the 1920s and '30s, these researchers discovered that the human ear does not respond linearly to sound. In fact, our sensitivity to sound is more acute for frequencies that are between 2000 Hz and 5000 Hz, and this sensitivity varies as the overall sound level increases or decreases. Thus "weighting filters" were developed to ensure that sound level instruments responded more like the human ear. In English-speaking countries, the "A-weight" curve is used since it approximates how we hear low- to medium-level sounds (other weighting filters are used for louder sounds, such as jet engines). Similar weighting filters are used in other countries.

The use of weighting curves for sound-level measurements was an important first step, but weighted measurements still don't reveal enough to explain why some noises are more annoying than others. Often, reducing the components that contribute the most to "annoyance" is often more important than reducing the overall noise level. A good example is the acoustic engine response inside a car as the driver increases speed. The goal is to get a characteristic but pleasant sound response and not one that is annoying. Unfortunately, frequency information from 1/1- and 1/3-octave measurements provides only the most basic clues for designers as they struggle to make products that are more pleasant.

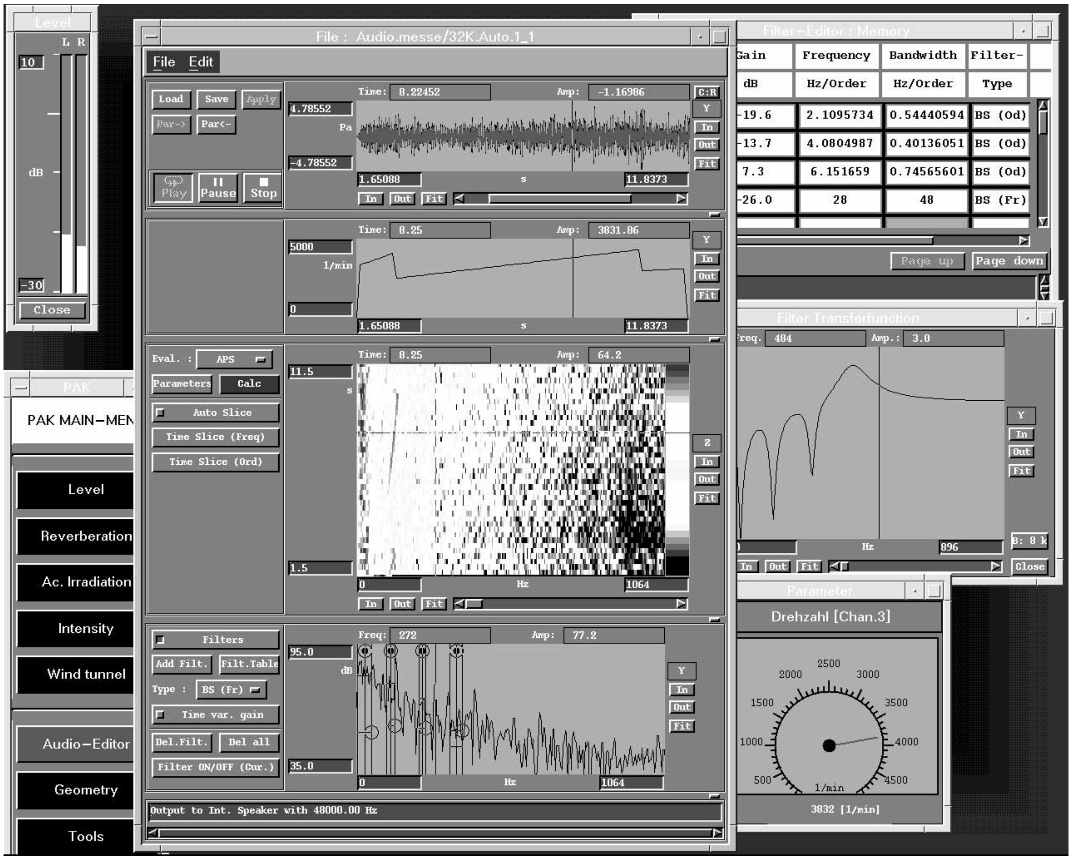

Figure 3
Engineers modify recorded time histories by applying filters and listening to the effects with the PAK acoustic design tools.

Psycho-acoustics *quantifies* our reaction to noise components

Psycho-acoustics uses the most current understanding of human hearing and the psychological effects of noise to measure, quantify and identify key components of a noise signal that must be reduced to diminish their annoyance to the human ear. Psycho-acoustics isn't new, but it's become remarkably sophisticated within the past few years, in part due to new research in the field and to improvements in signal-processing technology. Basic psycho-acoustics measurements deal with four "hearing sensations"—*loudness*, *sharpness*, *variation (fluctuation strength)* and *roughness*.

Instationary loudness (see figure 1) is a measure of the magnitude of noise volume and also reflects the time and spectral masking effects characteristic of the human ear. It is measured in *sones* (from the Latin word *sonare*, "to sound"). A *sone* is referenced to a 1 kHz tone at 40 dB_{SPL}. A noise that appears to be twice as loud as this reference would measure 2 sones.

Sharpness is used to characterize steady-state noise, and is a measure of the proportion of loudness within critical frequency bands. For example, two different types of noise may have equal loudness, but the one with greater sharpness will have louder frequency components within frequency bands to which the human ear is particularly sensitive (in the world of music, the "timbre" of a sound is related to its sharpness). Sharpness is measured in *acum* (from the Latin word *acer*, "sharp"). An *acum* is referenced to a narrow-band noise centered at 1 kHz with a level of 60 dB_{SPL}.

Fluctuation strength (sometimes called "variation") is used to characterize dynamic noise by measuring the temporary deviation of the loudness spectrum due to frequency modulation between 0.25 Hz and 20 Hz. Fluctuation strength is measured in *vacil* (from the Latin word *vacilare*, "vacillate"). A *vacil* is referenced to a 1 kHz tone at 60 dB_{SPL} that is frequency-modulated by a 4 Hz sine wave with a modulation factor of one.

Roughness is used to characterize dynamic noise by measuring the temporary deviation of the loudness spectrum due to frequency modulation between 20 Hz and 300 Hz. Roughness is measured in *asper* (from the Latin *vox aspera*, "rough voice"). An *asper* is referenced to a 1 kHz tone at 60 dB_{SPL} that is frequency-modulated by a 70 Hz sine wave with a modulation factor of one.

Solutions for psycho-acoustic analysis

As you can imagine, the kind of processing power required to apply psycho-acoustics analysis to noise measurements made it cost-prohibitive until recently. But today, powerful DSP workstations have made the technology available to leading companies around the world. One such system is PAK, an acoustics test stand developed by the German firm Mueller-BBM GmbH (see figure 2). This uses an HP 3587S VXI workstation to form the core of a powerful acoustics test system that includes psycho-acoustics.

The PAK system makes sophisticated noise measurements, then lets designers view (and listen to) effects of proposed acoustic treatments without having to modify the device-under-test. In addition to the psycho-acoustics software module, PAK includes modules for tracked analysis, including FFT, digital nth octave and digital order analysis. The Audio Editor is a tool for acoustic design (allowing designers to listen to and simultaneously modify the sound signal with digital filtering), A/B comparison, mixing, cutting and synthesis (see figure 3). Other modules include reverberation, operational deflection shape analysis, acoustical irradiation and intensity measurements. The system provides scaleable hardware and software for multichannel applications up to 256 inputs. ■

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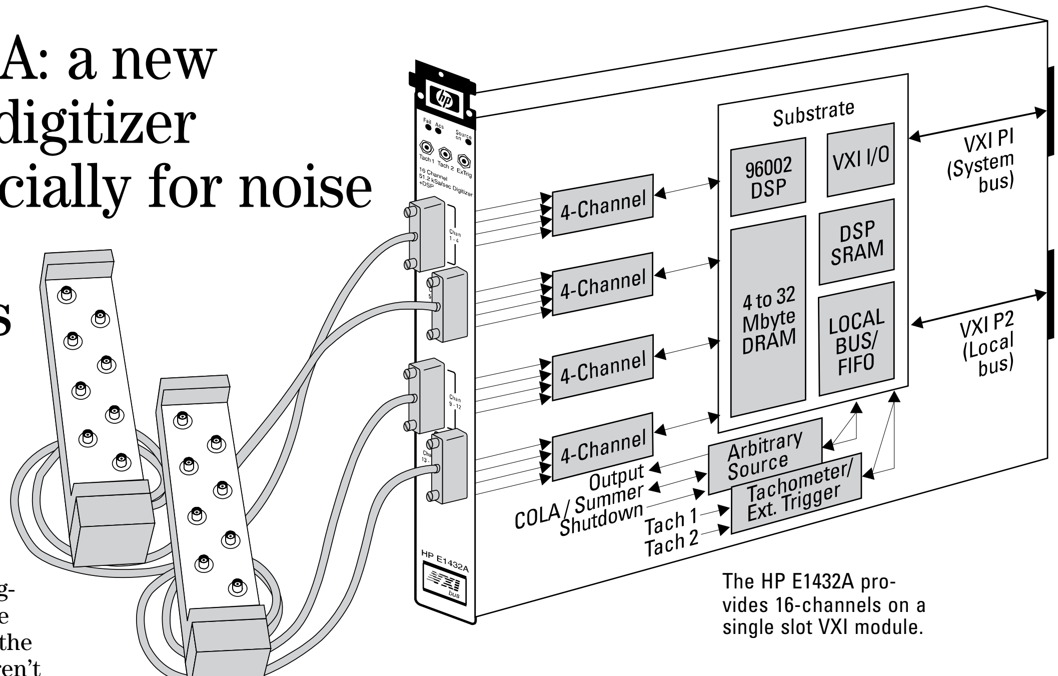
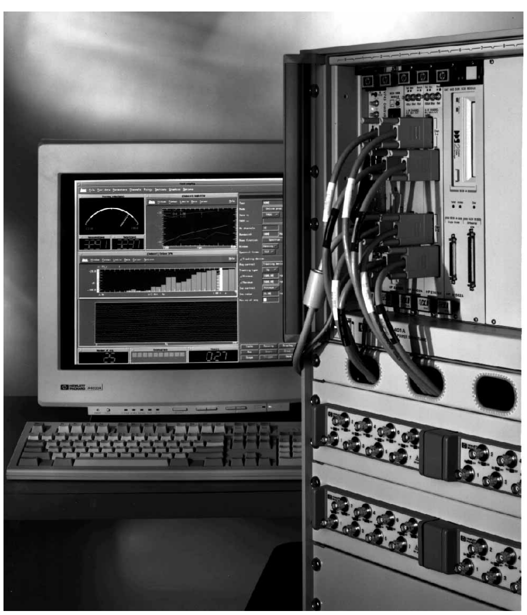
For more information on the PAK system, please check 1 on the Reply Card.

The HP E1432A: a new multichannel digitizer designed especially for noise and vibration measurements



The HP E1432A provides 16-channels on a single slot VXI module.

When HP went looking for suggestions for a next generation multichannel digitizer module following the introduction of the HP E1431A, LMS International[1] saw an opportunity. "For some time we had recognized the importance of VXI to the noise and vibration community—the VXI concept is great—but we weren't convinced that the technology had matured to the point that it could handle all of our measurement needs," explains Dr. Jan Leuridan, LMS Chief Technical Officer. The LMS CADA-X integrated test laboratory covers a broad range of applications and measurement needs: modal, acoustics, psycho-acoustics, rotating machinery analysis and vibration control, to name just a few. LMS needed a very versatile multichannel digitizer with high performance and a price tag that wouldn't break their high channel-count customers.



Up to 160 channels will fit in one VXI mainframe.

The result of the HP and LMS International cooperation is the HP E1432A 4- to 16-channel digitizer. This *single-slot* VXI module features up to 16 channels, onboard DSP and a 4- to 32-MByte first in, first out (FIFO) buffer, with room left over for an optional 20-bit arbitrary source or an optional two-channel tachometer. "This new digitizer from HP will meet the needs of our most demanding customers. We now expect VXI to become the platform of choice for noise and vibration testing," Leuridan said. Key performance specifications include a fully alias-free 20 kHz per channel frequency span and 90 dB dynamic range.

Signal conditioning breakout boxes allow you to mix transducer types on a single digitizer module. Inputs types are voltage (e.g., proximity probes), ICP and microphone inputs. Inputs are true differential for excellent noise rejection.

LMS CADA-X users often have high channel-count systems. This fact put two somewhat contradictory design requirements on the digitizer definition: It had to have scaleable performance and yet be inexpensive. In the past, users have had to trade off system performance and channel count. With the HP E1432A on-board DSP hardware, all of that changes—you can have all the channels you want without sacrificing performance. With on-board DSP, system performance remains constant as you add each new block of channels.

With stiff performance requirements, keeping the price low was a real challenge. HP R&D engineers accomplished this by putting 16 input channels, the on-board DSP, the FIFO and the optional source or tachometer into one single-slot VXI card. With this functional density, manufacturing costs are lower and each system requires fewer mainframes. A single mainframe can now hold up to 160 channels, with room left over for a HP V743 embedded controller and two system disks. ■

For more information, please check 2 on the Reply Card.

[1] LMS International is a leading supplier of systems for noise and vibration testing and a long-time Hewlett-Packard channel partner.

The HP E3203A: now custom systems are within the reach of every potential user

The HP E3203A Measurement Engine supports the new HP E1432A 16-channel digitizer.

Now it's easier—and faster—than ever before to develop a custom system for noise and vibration testing. The new HP E3203A Measurement Engine software is a library of 100+ high-level function calls that let system integrators rapidly develop high-performance dynamic data acquisition and analysis systems. Each of these function calls typically replaces hundreds of lines of code.

You'll enjoy reduced program development time in four ways:

- The amount of code required for any task is drastically reduced.
- Quality audit demands are correspondingly reduced.
- Hardware functions are controlled via high-level functions (you don't have to learn the gory details of the data acquisition hardware)
- You don't have to become a DSP expert

Most important, you end up with a very high-quality and high-performance program because of the quality verification and DSP expertise built into these functions.

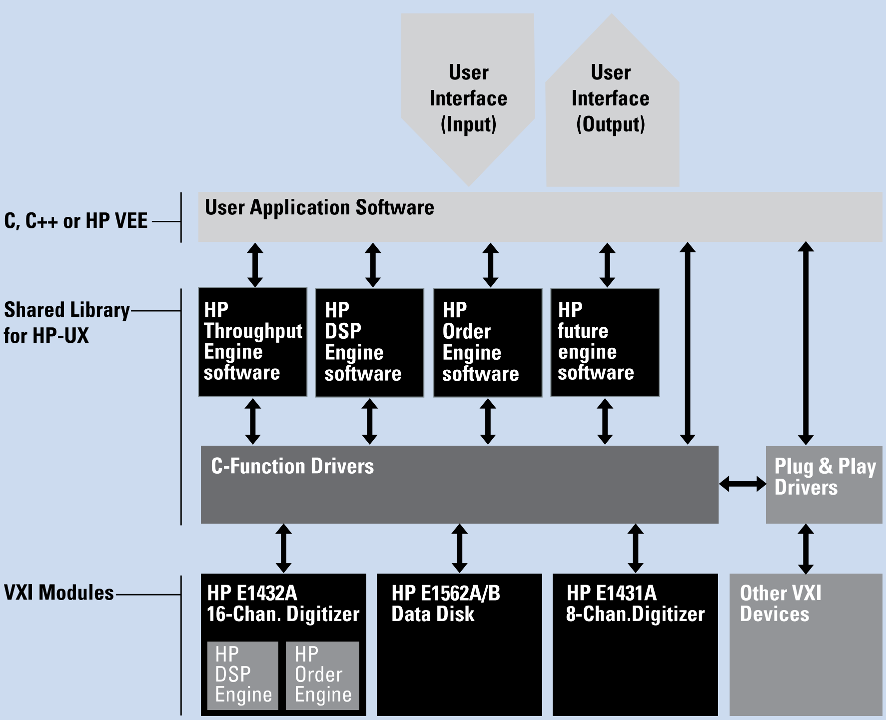
Measurement Engine is the second generation DSP engine library from Hewlett-Packard. Like its predecessor, the HP E3203A provides high-speed multichannel throughput to the HP E1562A/B 2- or 4-Gbyte data disk. Using the recently introduced HP E1432A 4- to 16-channel digitizer, up to 45 channels of data sampled at 51.2 kSa can be throughput to disk for 700 seconds without missing a single byte of data. (See the accompanying article for a description of the HP E1432A.)

An optional order tracking library called the HP Order Engine is available with the HP E3203A. This is a library of functions that adds access to HP's computed order tracking algorithm to the HP E3203A. Computed order tracking provides completely alias-free and accurate order tracking for fast run-ups and run-downs, without requiring external tracking filters and ratio synthesizers. The HP Order Engine adds a new capability to HP's computed order tracking—the implementation of traditional external sampling.

The HP E3203A Measurement Engine is available as a shared library for use with HP ANSI C, C++ and HP VEE in HP-UX. (HP VEE is a graphical programming environment that greatly increases programming productivity in its own right.) ■

For more information on the HP E3203A Measurement Engine, check 3 on the Reply Card.

For more information on HP VEE, check 4 on the Reply Card.



The HP E3203A Measurement Engine is a building block for fast, powerful data acquisition and analysis programs.

C-Function Drivers

Realtime Answers

Q. My PC can't seem to read data I saved on a floppy disk from my HP 3563A. This used to work when I used the LIF utilities; what's happening?

A. The problem is a change in technology. The HP 3562A and 3563A support CS-80 disk drives such as the HP 9122 and 9153. The analyzer controls the drive—reading, writing, cataloging and initializing disks. These models have a built-in 3.5-inch floppy disk that makes them ideal for carrying data from the analyzer to your PC. However, these disk drives format any media as low density and virtually all new 3.5-inch disks are high density.

The most likely cause of your difficulty is the PC trying to read your low-density media as high density. Hold the disk by the label with the door facing up. In this orientation the write protection tab will be in the lower left-hand corner. Your PC determines if a disk is low density or high density by the presence of a hole in the lower right-hand corner of the disk housing. Your PC is probably detecting this hole and then applying high-density read and write standards to your disk.

Take a piece of opaque tape and cover the hole in the lower right-hand corner of the disk. Now your PC and the LIF utilities will once again be able to read your data. It's important that you always use the analyzer to format your 3.5-inch disks, otherwise you may create an unreadable volume due to density mix-ups.

Q. How can I get hardcopy output from my HP 3562A?

A. The HP 3562A and 3563A can send an image of the display to HP-GL (Hewlett-Packard Graphics Language) plotters. In recent years, HP-GL plotters with an HP-IB interface have largely been replaced by serial and parallel color printers that do not understand HP-GL. However, you still have many alternative ways to get a copy of your analyzer display.

Alternative 1. HP can provide refurbished HP-GL plotters with HP-IB interfaces. The simplicity of this option is attractive. With a plotter and an analyzer, you have all the required tools to make as many hard copies as you wish. Information regarding refurbished plotters is available from your local HP Test & Measurement representative.

Alternative 2. Use stored data to recreate measurement displays. The HP 3562A/63A can control HP-IB CS-80 disk drives, allowing you to save measurement data to disk. The HP Standard Data Format Utilities (SDF) include programs that can find these disks on the HP-IB and can read the CS-80 disk files using a PC. The SDF Utilities will allow you to copy files from the CS-80's Logical Interchange Format (LIF) to the DOS format on your PC. Once the file is in a PC compatible format, you can print it using tools for DOS or for Windows.

DOS Solution: In DOS you can display the files using the VIEWDATA program included with SDF. VIEWDATA will allow you to plot, print or do a screen dump to your local hardcopy device. Plotting requires an HP-GL plotter. Printing requires a PCL printer (for example, LaserJet or DeskJet.) Screen dumps use the DOS print screen functions and the DOS "GRAPHICS" command.

Windows Solution: You can display measurements in the Windows environment using the HP 35639A data viewer. The data viewer allows you to send graphics or data to any hardcopy device supported by Windows, and it also makes it easy to create reports and special forms to display as many traces, markers and labels as you wish.

Alternative 3. Transfer data directly to a PC using the program called HPIB63 included in the SDF utilities. With this program and an HP-IB card in your PC, you can copy the active trace from the analyzer to a binary file on the PC. The utility is simple and direct:

HPIB63 <filename> /A:<address>

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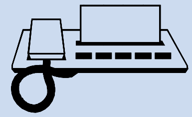
It will even find the HP 3562/63A on the HP-IB if you do not specify the bus address. The file created is a binary data file and must be converted to graphics by a program such as VIEWDATA or the HP 35639A data viewer if you want to make a hardcopy.

Alternative 4. Plot directly to a PC. If you have a PC with an HP-IB interface card, you can use the SDF Utility SOFTCOPY. This lets the PC emulate a hardcopy device such as a plotter or a printer. On the PC you would execute the command:

SOFTCOPY [filename] /A:<address>

This resulting file can then be copied to a plotter on the PC's serial or parallel port. We recommend you use a binary copy command such as COPY APLOT.PLT LPT2 /B. The file may also be imported directly into word processing programs that have HP-GL filters (such as Microsoft Word for Windows.) Note that this technique also works for other HP products that can print to an HP-IB port.



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101	Index of available data sheets
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35670	HP 35665/35670 User Course data sheet