REALTIME

Update

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A Newsletter for Noise, Vibration and Electromechanical Test Professionals

Better, Safer Power Generation Measurements in Less Time

by John Demcko and John Jensen

If you're trying to boost efficiency in an electric power plant, the solution might be sitting in one of your labs already. Dynamic signal analyzers (DSAs) have been helping power plant engineers monitor and diagnose vibration problems for years, and now they're expanding into both electrical tests and new areas of electromechanical testing, too.

Making these tests with a DSA delivers five major benefits:

1. You can make measurements using much smaller test transients, putting less electrical and mechanical stress on the machine under test.

2. The DSA can do all the data capture, which previously required strip chart recorders, digital oscilloscopes and analog or digital tape recorders. One instrument will often do everything you need.

Also in this issue:

3. You can easily view test results in either the time or frequency domains. Frequency domain measurements provide better phase accuracy than you can get with graphical measurement techniques in the time domain.

4. Display markers help you extract detailed information from digitized time and frequency records quickly and accurately.

5. In addition to all these benefits, DSAs often reduce test times, too.

The list of ways you can apply DSAs in power plants tests is even longer than the list of benefits. Here's a quick look:

- **Power system stabilizer tuning:** This was one of the early DSA successes we had at Arizona Public Service (see figure 1). Using the DSA's random noise stimulus instead of the stepped sine method we'd used previously, we cut the test time from 3 or 4 hours to 14 minutes and subjected the machine to much less potential stress.
- **Grounding resistor sizing:** In this application, we used a DSA to make on-line impedance measurements to check for proper grounding in a turbine generator auxiliary system. The technique delivered accurate measurements while isolating the test personnel from high voltages.
- **Power line quality:** DSAs can measure line frequencies and harmonics with accuracy of better than 0.1%.
- **Relative and absolute phase measurements:** The accuracy of phase measurements is one key factor in converting many users to DSA. Plus, coupling a DSA with an HP precision global position system makes it possible to perform grid stability analysis and fault location to within ±200 feet.
- **Measuring power or rotor angle:** A good DSA equipped with an appropriate transducer can deliver accuracy better than 0.5 degrees in these measurements, compared to the

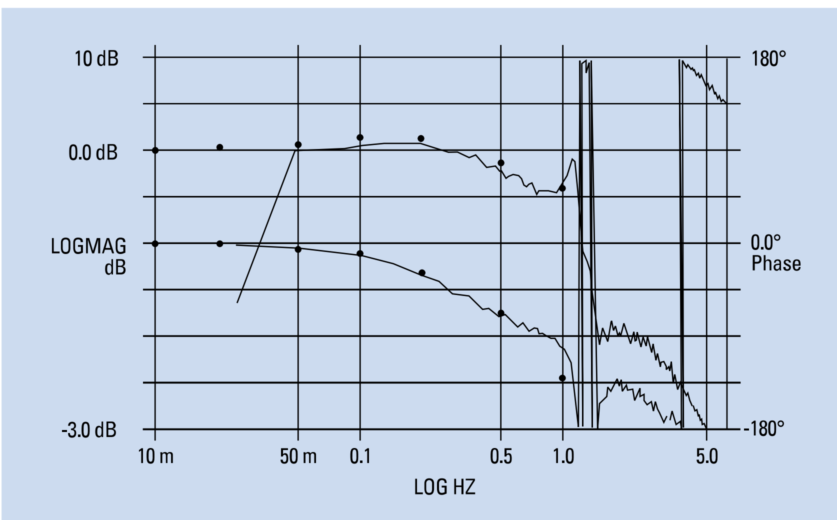


Figure 1A: Comparing DSA and stepped-sine testing

In this test on a generator operating at 246 MW, the DSA measurement clearly shows a local mode between 1.0 and 1.1 Hz. The stepped sine measurement (represented by the eight gain and phase points) missed this critical information completely.

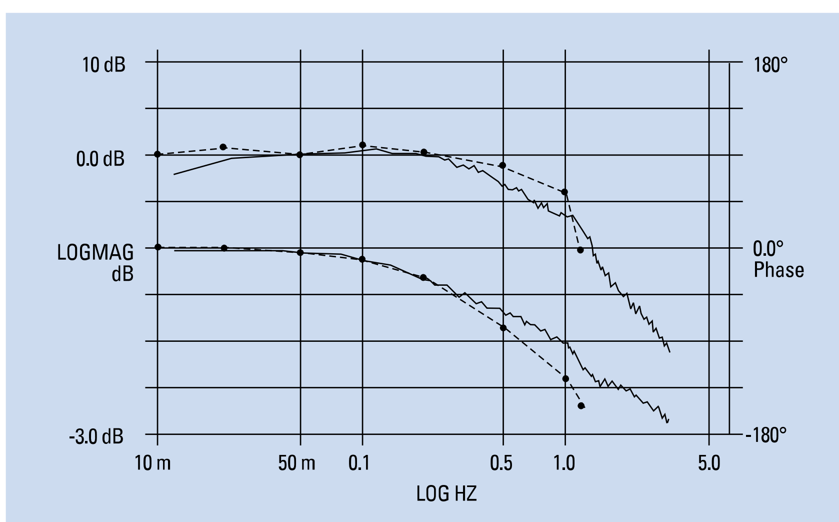
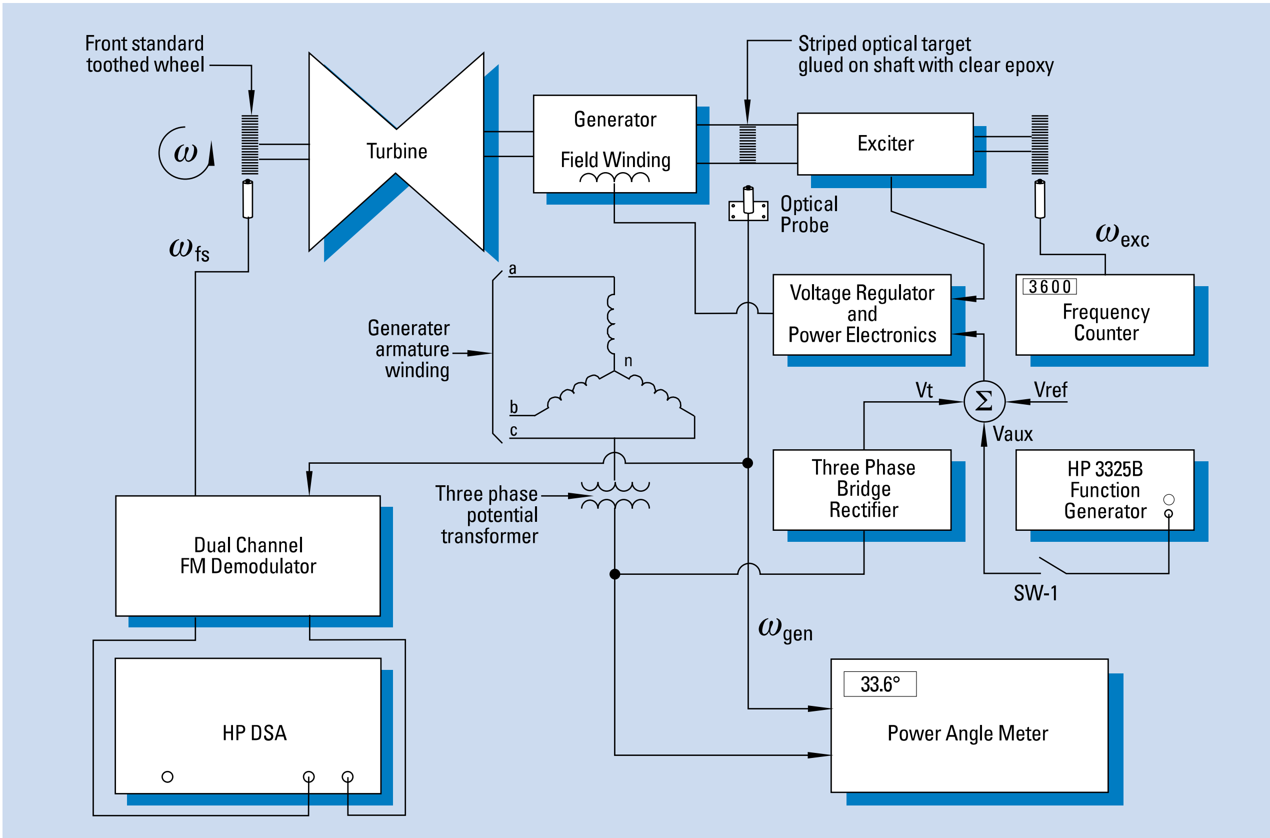


Figure 1B: Frequency response at different operating levels

With the output reduced to 150 MW, the local mode shown in Figure 1a is no longer visible.



5 degrees offered by the old strobe and chalk line approach. DSAs deliver much more information, too, including key parameters such as overshoot and settling time. And the DSA is much safer, since test personnel don't need to be near an operational machine in order to make measurements. Figure 2 shows a typical instrumentation setup for measuring power angle.

- **Apparent impedance measurements:** Estimating worst-case impedance can leave a lot of money on the table by causing you to run significantly below safe power transfer limits. Improved measured accuracy can give you a better idea of apparent impedance over a range of frequencies, which can lead to more informed and consequently more efficient utilization of generating capacity. This is a great example of how better measurements can boost your bottom line.
- **Shaft torque and subsynchronous vibration:** DSAs provide better monitoring of these two major sources of turbine fatigue and failure.
- **Rotor torsional resonance testing:** Engineers at a number of generating facilities have explored different ways to measure torsional resonances, relying on narrow frequency resolution and other DSA features to provide accurate data for in-depth modal analysis.

If you'd like to learn more about these tests and other aspects of using DSAs in power generation tests, ask for a copy of a white paper we've prepared entitled "Power Generation Measurements with HP Dynamic Signal Analyzers." It describes each of these measurements and explains how a DSA can deliver better results in less time. The publications referenced in the paper also provide more information. ■

Figure 2: Instrumentation for measuring power angle and torsional vibration

Here's a typical collection of sensors and measurement hardware needed to measure both power angle and torsional vibration.

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To receive a copy of the white paper discussing power generation tests, check 1 on the Reply Card.

HP Dynamic Signal Analyzers Meet New API Test Standard

The American Petroleum Institute has put a new spin on pump vibration testing. The revised API Standard 610 specifies, among other things, that the instrumentation you use must be capable of accurately measuring peak and rms values of different waveshapes. The bad news is that the standard also requires engineering units scaling, which rules out much existing measurement equipment. The good news is that HP dynamic signal analyzers have all the capabilities needed to meet the specification—as well as many more that will make your measurements accurate and productive.

A new twist on measurement standards

Normally, standards specify requirements for measured results, allowing equipment vendors to determine the most cost-effective implementation for obtaining those results. The revised API 610, however, also delineates *how* the peak and rms detection is to be implemented. The specified implementation cannot be met by most current measurement devices. The new requirements exclude older digital vector filters and most older dynamic signal analyzers, as well as other low-cost instruments that could supplement the measurement capability of existing vibration analyzers. Current HP DSAs, however, easily meet the new requirements.

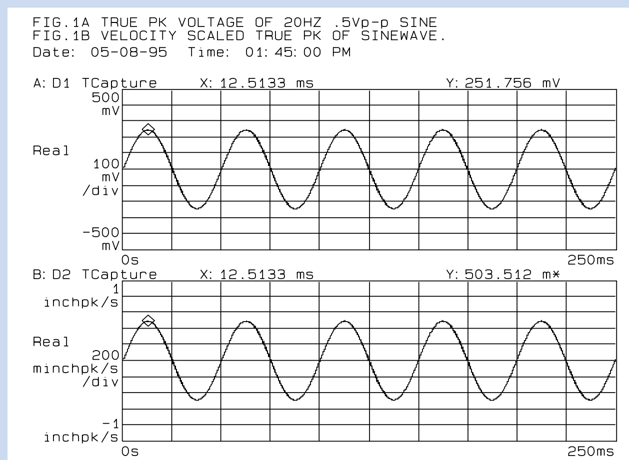
The two principle changes in API 610 require that the vibration analyzer used must have true peak and true rms vibration level detection in the unfiltered mode. Appendix S of the revised standard contains performance verification procedures to determine whether an analyzer may be used to make measurements to the standard. The following sections look at the true peak and true rms requirements in detail and explain how to make those measurements with an HP DSA.

True peak velocity detection

To qualify for this part of the standard, an analyzer must be able to accurately measure the peak value of two different waveshapes, a sine wave and a square wave. Here's how it's written:

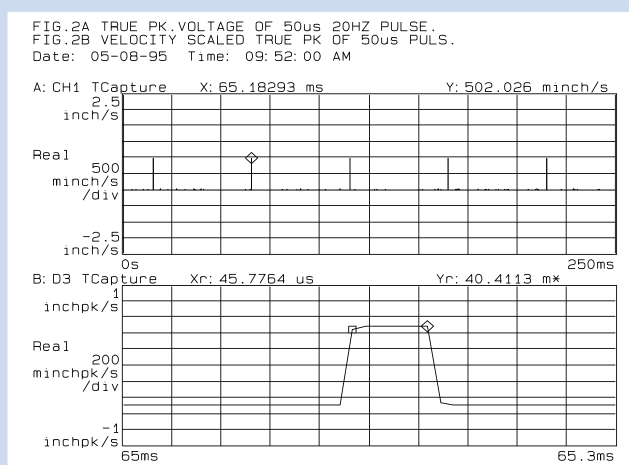
1. Input a 20 Hz sinewave of 500 mVpk-pk. The analyzer should measure 500 mVpk-pk.
2. Scale the voltage by a 500 mV/in/s velocity scaler.
3. Change the test source to a 50 μs-wide pulse train with a 20 Hz repetition rate. The analyzer must read out a velocity scaled peak of 0.5 in/s ± 7% (± 0.035 in/s).

A low-cost digital oscilloscope would measure the voltage peaks very easily, but could not meet the scaled velocity readout requirement. This low-cost supplement to existing vibration analyzers is therefore not allowed.



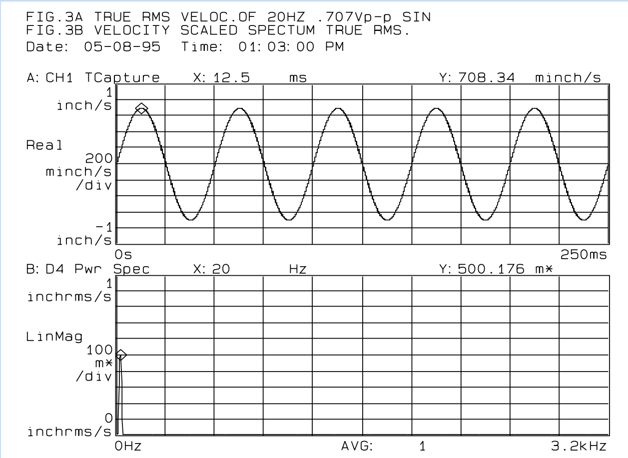
Figures 1A and 1B: Detecting true peak velocity

Here are the correct readings for the true peak velocity test.



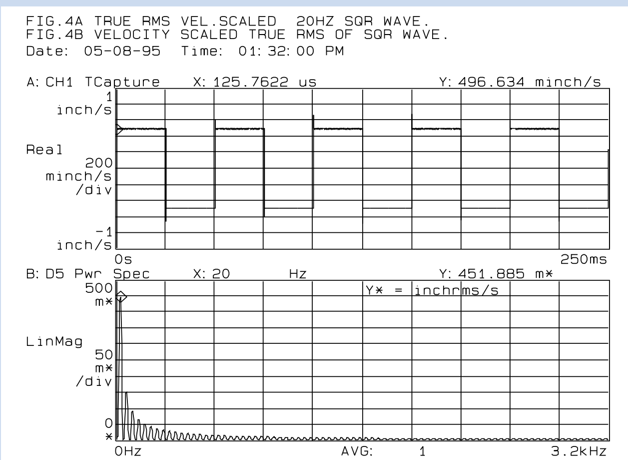
Figures 2A and 2B: Getting additional benefits from stored data

The HP DSA captures and stores data using continuous sampling, giving you many troubleshooting and analysis opportunities.



Figures 3A and 3B: Detecting true rms on a sine wave

This measurement result from an HP DSA confirms the true rms test on a sine wave.



Figures 4A and 4B: Detecting true rms on a square wave

The second part of the true rms test involves a square wave, with correct waveforms and band power shown here.

HP DSAs use the following procedure to demonstrate compliance with this true peak requirement.

1. Select the histogram or time (unfiltered) measurement mode.

2. Measure a time capture of 250 ms of data at a 7.63 μs sampling rate on two channels. Figures 1A and 1B show the correct readings, 0.25 mVpk and 500 milli-inches/second.

3. Display as in Figure 2A. The analyzer's default envelope display mode displays the peaks in the capture buffer. Note that the analyzer again displays the correct 500 milli-inches/second value of the pulse waveform.

4. Expand the time capture buffer around a peak, as shown in Figure 2B. The marker read out should be 0.5 ±0.035 in/s as shown in Figures 2A and 2B.

The HP DSA is doing continuous sampling at a 7.63 μs rate of the test signal. There is no dead time while the peak detectors are being reset. This approach collects a continuous data stream, not just one maximum and one minimum value in four revolutions, as the minimum specification requires.

An additional benefit of the HP DSAs is that you have all the collected data for further analysis. In other words, the HP DSA approach exceeds the requirements of API 610 and is much more likely to capture all vibration spikes—a powerful troubleshooting feature.

True rms measurement

API 610 specifies the following procedure for the true rms performance verification test:

1. Input a 20 Hz sine wave of 0.707 Vpk-pk.

2. Apply a velocity scale factor of 0.5 V/in/s. The vibration analyzer must display a scaled reading of 0.5 in/s rms ±7%.

3. Input a 20 Hz square wave with a 500 mVpk-pk amplitude to the analyzer in the unfiltered mode and set to the rms detection mode. The analyzer must read 0.5 in/s ±7% (±35 milli-inch/sec).

Except for the scaled velocity readout requirement, you could do this measurement with a low-cost digital voltmeter that measures true rms.

HP DSAs also meet the true rms portion of the performance verification. In fact, the DSA will provide true rms values in several display and measurement modes.

1. Select the unfiltered (histogram/time) mode.

2. Collect 0.256 seconds of data in the time capture buffer at a 7.63 μs sample rate on two channels.

3. Set the analyzer to the FFT mode, with the measurement span set to 3.2 kHz and 800 spectral lines. This results in a time record length of 0.25 seconds.

4. Compute the true rms results using the power spectrum measurement and the band markers function by selecting "RMS SQRT (PWR)." Figure 3A shows the sine wave. Figure 3B shows the power spectrum with the correct band marker reading of 500 milli-inch rms/sec.

5. Change the signal to a 20 Hz square wave of 500 mVpk-pk (250 mVrms). Figures 4A and 4B again show the correct waveforms and band power.

Additional DSA Benefits

Besides simply meeting API 610 requirements, using an HP DSA for pump vibration qualification testing delivers a number of advantages over other approaches:

- HP DSAs have from 2 to 48 analog inputs. Multiple inputs improve test productivity by producing multiple results at each pump operating test point while minimizing transducer switching.
- If data are throughput to the capture buffer, you can extract different types of data and spectra. The capture file can be used to produce simultaneously any five or more orders of pump vibration data for two or more inputs, not just the first five orders. Another pass through the capture file could provide FFT power spectra tagged with rpm, for instance.
- Math functions easily convert vibration data, so you can convert acceleration spectra to velocity or displacement in English or metric units with just a couple of key strokes.
- If you capture a pump rundown, you can extract an rpm spectral map and order track on five or more orders on two or more channels of data at once. At no time do you need to set up and calibrate a tape recorder or rewind an analog tape because the capture buffer provides random access to the data. You simply change the test type by recalling a previously stored test setup and press the Start key.
- Writing the report and plotting the data can easily take longer than acquiring the data. HP dynamic signal analyzers all come with utilities to port the data to a PC. An optional MS Windows software package (HP 35634A) is available to help turn data into information. This package helps with standard page layouts of data-plots and allows easy annotations of spectral peaks, frequency (speed) and amplitude. The choice of standards in software environments ensures lowest support costs and longterm support for the management of your data, easier expansion as future needs expand and easy (automatic) linkage of data to your report generation. ■

Realtime Basics

A Refresher Course on Windowing and Measurements

In these days of digital instrumentation and PCs, it is easy to forget that physical phenomena are analog and that windows are not always operating systems. Windowing and digitization meet in the process of dynamic signal analysis. This article explains the need for windowing and describes the advantages of common windows used by FFT-based analyzers.

What happens if you don't do windows

FFT analyzers transform data from the time domain to the frequency domain by computing the fast Fourier transform. It is based on the Fourier integral ($\int_{-\infty}^{+\infty} x(t)e^{-j2\pi ft}$), but is a form that can be computed numerically. The integral requires that a continuous signal be integrated over infinite time. Out here in the real world, of course, we want our results in finite time. And because computers work with numbers, we need to digitize the waveform, which makes it discrete in time. Both of these changes to the signal result in errors in the computed frequency spectrum. Sampling the signal at discrete times can cause *aliasing* (which can show up as "phantom" signals on the display). Changing the limits of integration from infinity to a finite length can cause an error known as *leakage* (which appears as energy from a particular point in the spectrum being "smeared" up and down across the spectrum).

Since it's impossible to measure a signal for an infinite time, the analyzer changes the limits of integration to the length of time it takes to collect a block of samples. This block of samples is called a *time record*. The FFT requires that the signal within the time record be repeated over and over again throughout time. If the repeated time records actually look like the original signal, no leakage will occur. If, on the other hand, they do not look the same, leakage will occur. Applying a window function to the data can help decrease the effects of leakage in the frequency domain.

If the time record contains an integral number of cycles of a continuous waveform, such as a sine wave, the waveform is said to be periodic in the time record. The value of the signal at the beginning of the time record is equal to the value at the end of the time record. When the time records are placed end to end, the start and finish points align exactly. The time record is indeed repeated over and over, and the Fourier integral can be computed accurately. No leakage occurs. Figure 1 shows a signal that is periodic in the time record.

Now, if a continuous waveform is not periodic in the time record, leakage will occur. When time records are placed end to end, the start and finish points don't align. This is like adding an instantaneous step to the waveform. Because an instantaneous step contains an infinite number of frequencies, these added frequencies contaminate the computed result. The power from the instantaneous step is spread across the spectrum, resulting in the leakage shown in figure 2.

FFT analyzers use windowing to reduce the effect of leakage, thereby improving the results in the frequency domain. The various window functions have different advantages, and it's important to choose the correct one for each measurement. The most common are the Hann, flattop, uniform, and force/response windows.

The Hann window

Use the Hann window to identify closely spaced frequency components or to measure broadband noise. The Hann function (it's named after a fellow named Hann, in case you're curious) looks much like a bell-shaped curve, varying from zero on the ends to unity in the center. Figure 3 illustrates the effect of the Hann window. Compare these traces to the same signal shown unwindowed in figure 2.

The Hann window's good frequency resolution comes at the cost of poor amplitude accuracy, however. Because the FFT acts like a set of parallel filters, signals not at the center of the bandpass filters see some attenuation. When you use the Hann window, a frequency falling midway between the filter's center frequency is attenuated by up to 1.5 dB.

The flattop window

If accurate measurement of amplitude is important, use the flattop window (figure 4). The flattop provides excellent amplitude accuracy, with amplitude variations reduced to less than 0.1 dB. But, again, you'll face a tradeoff. The flattop window gives you excellent amplitude accuracy but gives up some frequency resolution. The skirts of the filters are so wide that you lose some ability to resolve small frequency components spaced near large components.

The uniform window

The uniform window is really no window at all. It is sometimes called the "boxcar function" because it looks like a boxcar, a pulse that is unity for all values of time. The uniform window provides the best frequency resolution and amplitude accuracy, but can only be used if the measured signal is periodic in the time record. This condition is rarely met with naturally occurring signals, but can be met in controlled testing. Because the frequency of any applied signal can be known, it is possible to

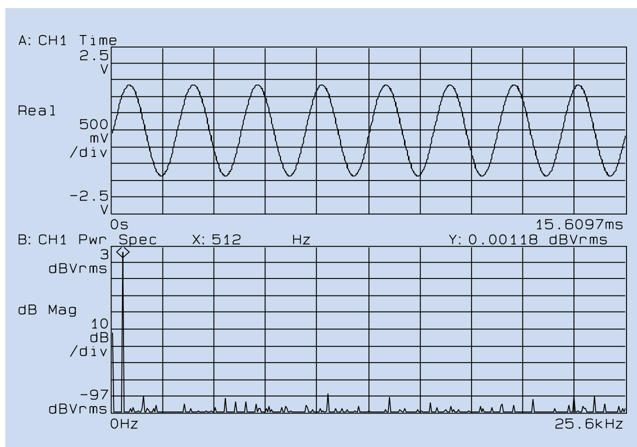


Figure 1: Signal periodic in the time record

The sine wave in the top trace is periodic in the time record, so no window (the uniform window, actually) is needed. The lower trace shows the clean frequency domain representation of this signal, with no noticeable leakage. Compare this with the signal in figure 2.

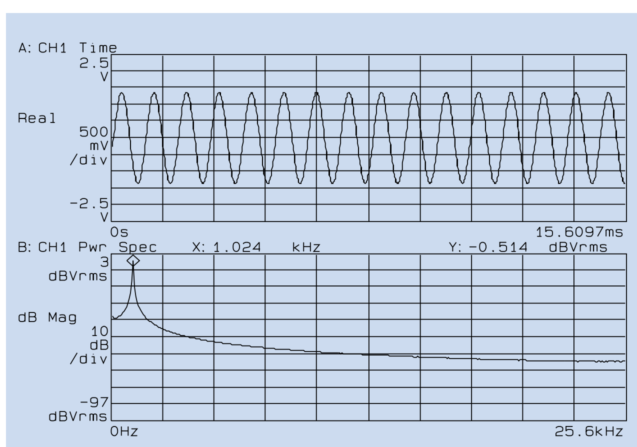


Figure 2: Signal not periodic in the time record

In this case, the sine wave is not periodic, and the bottom trace shows what happens if no window is used in the measurement. The energy spread across the spectrum is called leakage.

make sure that the signal is periodic in the time record and the frequency is centered in one of the FFT's bandpass filters. Because the signal is periodic in the time record, there is no leakage. And because it is centered in the bandpass filter, no amplitude inaccuracy is caused by attenuation. (The measurements in figures 1 and 2 were made with the uniform window.)

The force and response windows

Force and response windows are used for a specific application—computing the transfer function of a mechanical structure using an impulsive force excitation (see figure 5). A hammer or other impact device equipped with a force transducer is used to strike the structure and an accelerometer measures the structure's response vibration. The force transducer is connected to one input channel of the analyzer and the response accelerometer is connected to the second channel (in a simple single-input, single-output measurement).

The time record for the force should include only the impact with the structure. The movement of the hammer before and after striking the structure can cause stray signals in the time record. The force window (applied to the signal from the hammer) is unity where the impact signal is valid and zero everywhere else to eliminate noise.

The response window is applied to the accelerometer signal from the structure. This window ensures that the response signal decays to zero by the end of the time record. In fact, it's sometimes called the exponential window.

Do windows—and do them right

Even in these quick examples, you can see the effect windows have on your measurements, and how important it is to select windows that match your application and your test goals. So take a second or two before each measurement and think about what you're trying to accomplish. Selecting the right window will help you get the best answers possible. ■

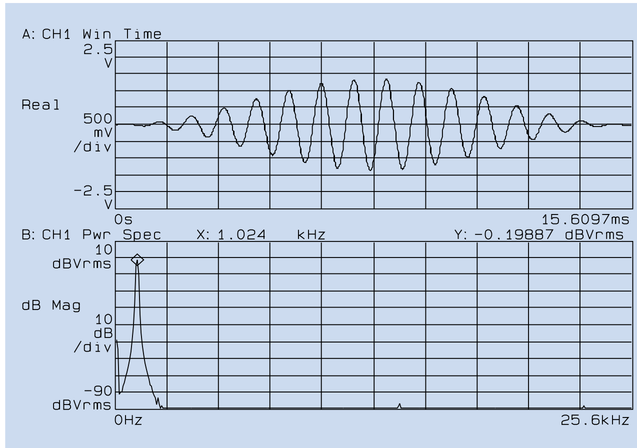


Figure 3: Applying the Hann window

Here's the effect the Hann window has on the nonperiodic signal from figure 2. The window reduced the leakage considerably and offers good frequency resolution, at the expense of some amplitude accuracy.

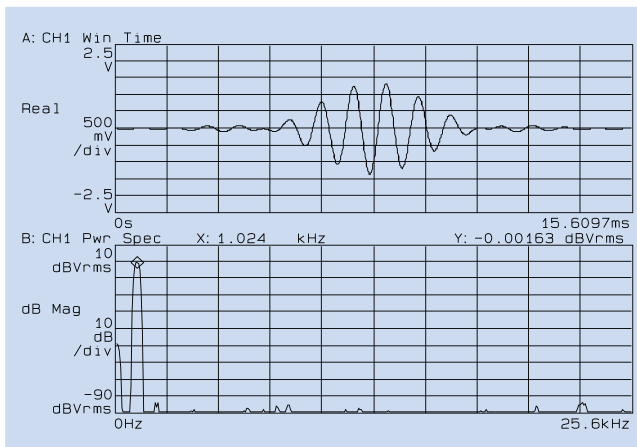


Figure 4: Applying the flattop window

The flattop offers better amplitude accuracy, but you can see it isn't as good as the Hann window at resolving closely spaced frequencies.

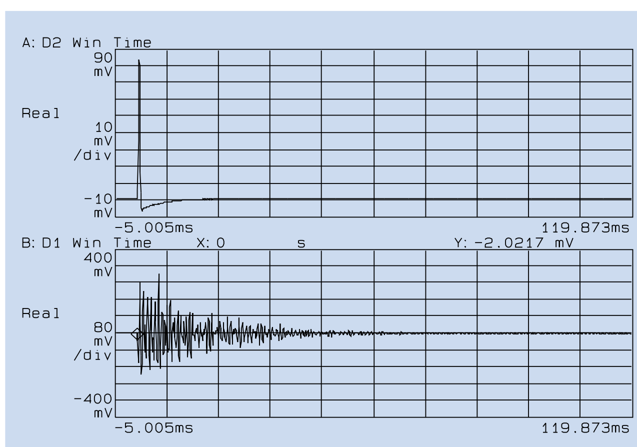


Figure 5: Applying the force and response windows

The top trace shows the effect of the force window; everything after the impact is set to zero. The bottom trace shows the effect of the response window, which forces the signal to decay exponentially until it reaches zero.

Realtime Answers

Q. I keep hearing about VXI. What is VXI and how is it different from VME?

A. VME and VXI are two standardized electromechanical architectures that specify the mechanical and electrical parameters needed to operate modular computers and instrumentation. VME preceded the development of VXI; in fact, VXI is an abbreviation for VME Bus Extensions for Instrumentation.

VME modules were commonly called Eurocards in the early 1980s. In 1982, a standard defining the VME bus was released. IEEE and ANSI granted approval of the standard in 1987. The mechanical portion of the original standard defines the connector pin assignments, power requirements, cooling and physical dimensions. Electrical specifications called out the communications protocol and defined methods of high-speed module-to-module communication.

Module-to-module communication has proved to be an exceptionally strong point in VME. Many modular minicomputer designs use the VME cardcage. Signal conditioning, data acquisition and measurement capability are also available in the VME platform.

The possibility of integrating instruments into a single mainframe capable of high-speed communication was the motivation behind extending VME. In 1987, the initial draft of the VXI standards was released for study. Since that time, many instrument suppliers have embraced VXI as the preferred platform for modular instrumentation.

For instrumentation, VXI has several advantages over VME. The VXI standards specify an electrical environment that has less noise than the computer-focused VME. VXI cardcages can support more precise analog measurements and higher performance measurements than VME can. In addition, VXI systems can be integrated easily using message-based modules. Further improvements have come about with the widespread adoption of plug-and-play software standards. Plus, VXI standards include larger card sizes than are commonly seen in VME, offering instrument designers more electronic real estate to develop test solutions.

The open standards for VXI have continued to attract instrument manufacturers and test customers. For instance, the VXI platform is displacing many military proprietary bus systems. Manufacturing test facilities are using the VXI environment because of its software portability, multiple vendor hardware capability and the security of using an open, accepted standard. Today more than 200 manufacturers are registered with the VXI Consortium, offering thousands of different modules.

Q. I'm installing my new HP 3566/67A version A.03.04 software and I keep getting a "Setup Toolkit Error." Are my new disks defective?

A. No, there is nothing wrong with your disks. Installing Windows programs requires the use of a setup utility provided by Microsoft. These Setup Toolkit errors result when the Windows operating system cannot find critical files that are needed.

Your files may have been overwritten by other installation programs that detected a difference between their version and yours. If you are using a LAN-based system, it is possible that these files are not in your path, or they may have been removed by the system administrator.

Try the following options:

- Run the 3566/67A A.03.04 setup program on a standalone PC. If it installs, your disks are OK.
- Re-install a different Windows application on your PC. If it installs, the setup libraries are OK. If this is the case, you should contact your PC support person to see if some other utility is interfering with the installation of your HP 3566/67A A.03.04 software.
- If all else fails, you will need to re-install Windows.

Q. I'm measuring the frequency response of some transducers, and my results look far too noisy. What am I doing wrong?

A. It's difficult to provide specific answers to this question, but there are some general rules for making good frequency response function (FRF) measurements. A brief review may help.

Be sure that your stimulus signal (noise, sine or impact) is connected to the reference channel. The response is defined as System Output/System Input. Using the system input as your reference signal is vital.

Make your measurement more than once by using RMS averaging. FRF measurements are susceptible to noise. If your output signal has one frequency with a "0" in it, the corresponding magnitude will be also be 0. Averaging several tests together avoids this noise sensitivity. Averaging is a must for good FRF results.

Use your supporting tools. All good signal analyzers have a coherence or variance function available for FRF measurements. These functions help you evaluate how well your input and output are related. Low coherence indicates that the measurement most likely did not work correctly. Re-evaluate the setup or add more averages and your results will improve.

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35670	HP 35665/35670 UserCourse data sheet

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