WHITE PAPER

Dynamic Data Acquisition System

KEYSIGHT

Introduction

For products in aerospace, telecommunication, automobile, the Internet of Things, renewable energy, and other modern industries, feature sets and performance have grown almost exponentially this century. Products have become more complex in terms of design, integration, and test characterization. To stay ahead of the product development curve, engineers need fast and accurate test systems. Companies need test systems that provide precision measurements across the widest range of signal types.

In addition to accuracy, speed, and resolution, your test system needs to capture dynamic signals that may be transient, imperfect signals that may have external noise perturbation, complex mixed signals, and more. This white paper discusses the importance of having a modern dynamic data acquisition (DAQ) capability in your test systems, its benefits, and types of applications. It also dives into the capabilities of a modern DAQ system.

A dynamic DAQ system lets you monitor the following:

- dynamic signals in exact window timeframes
- multiple dynamic signals simultaneously
- multiple types of dynamic signals
- dynamic signals in time and frequency domain

Dynamic vs. Static Data Acquisition

A traditional DAQ system scans all its input channels and logs measured data as it goes through each channel. Most DAQ systems are static. They generally take a single measurement as they scan each channel.

A modern DAQ system has dynamic data acquisition capability. As it scans each channel, it makes multiple samples of measurements (see Figure 1).

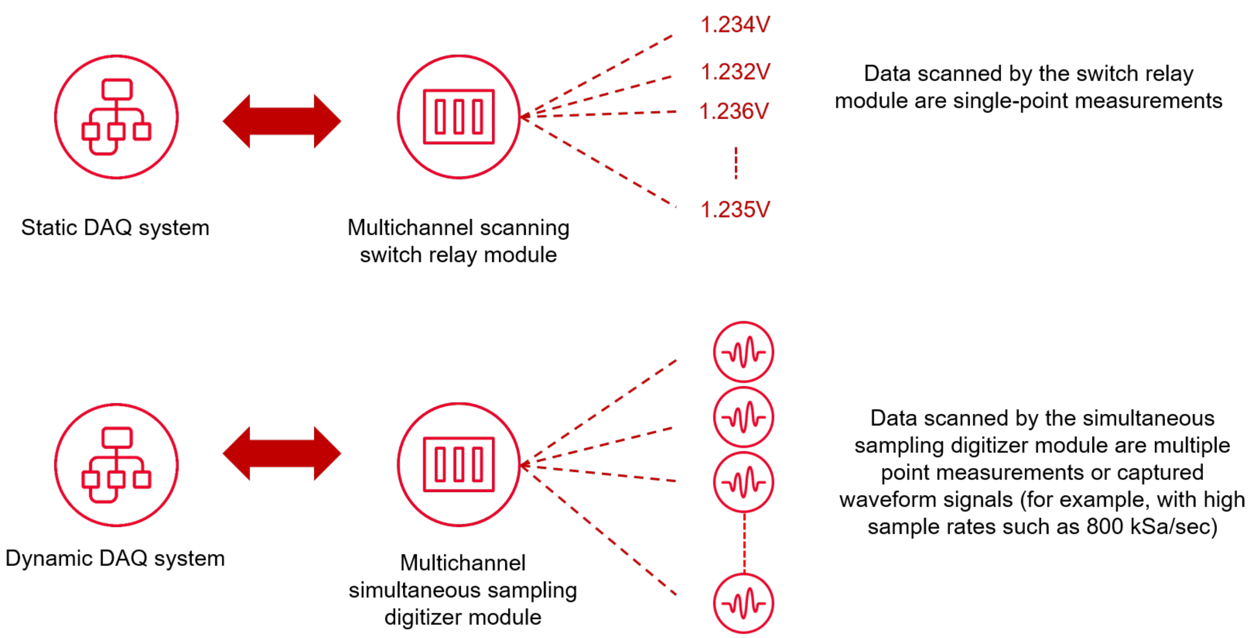

Figure 1. Dynamic vs. static DAQ system

Benefits of a Dynamic DAQ System

Dynamic data acquisition is not a new field in measurement science, but it is increasingly important in commercial and military applications. Static data acquisition gives us a glimpse of measurement periodically but cannot catch dynamic changes of impact shock stresses on a structure, vibration of a motor, or changes in environmental noise. Dynamic data acquisition ensures accuracy and reduces the errors and variability often associated with the acquisition and analysis of dynamic data. A handbook published by the Institute of Environmental Sciences and Technology can help you make accurate dynamic data measurements and analysis. [1]

Monitor dynamic signal at the exact window timeframe

In a dynamic data DAQ system, you can set the sampling rate of your acquisition and the number of points to capture. You can determine the window capture time with these two settings. However, be sure to choose the correct sampling rate first to capture the necessary details of the dynamic signal (see Figure 2).

Capturing a transient signal of an event can be tricky. If you have an electronic signal event trigger such as a transistor-transistor logic (TTL) signal, you can use an external trigger from your DAQ system to synchronize the capture of the transient signal. If not, use an internal threshold trigger to capture the transient signal.

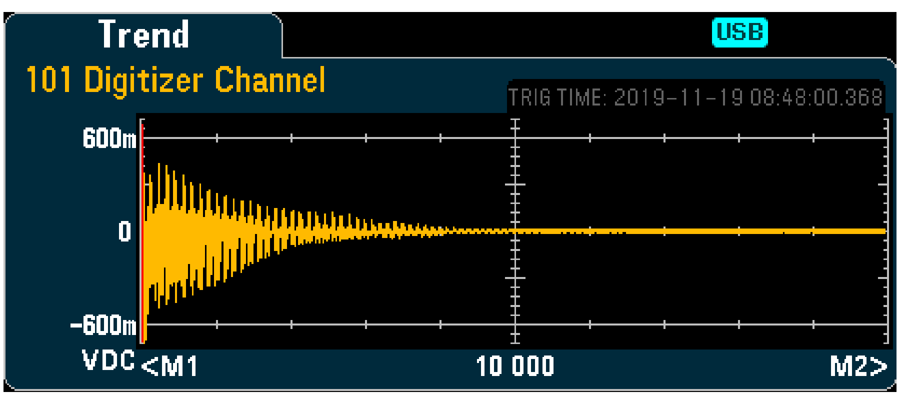

Figure 2. A window timeframe of a transient signal captured by a DAQ system

1 Himelblau, H., Wise, J. H., Piersol, A. G., & Grundvig, M. R. (2006). *Handbook for Dynamic Data Acquisition and Analysis: Design, Test, and Evaluation Division Reference Document 012.2*. Institute of Environmental Sciences and Technology.

Monitor simultaneous dynamic signals, all sharing the same time stamps

Modern dynamic DAQ systems can capture multiple dynamic signals simultaneously and time-synchronized too. Many applications, such as measuring multiple points of strain measurements on a physical structure or multiple points of electrical voltages on a motor, require this capability.

Figure 3. Multiple dynamic signals captured or monitored by a DAQ system

Some DAQ systems combine multiple actual measured channels into virtual computed channels using math and algorithms. These virtual computed channels bring more meaning to your viewing in real time. For example, if you measure the input voltage and current of a device, you can create a virtual input power channel (in watts) by multiplying the voltage and current input channels in real time.

Monitor multiple types of dynamic signals

Dynamic DAQ systems are generally quite versatile. One key capability is compliance with the Integrated Electronics Piezo-Electric (IEPE) sensor standard. These types of sensors have built-in circuitry to convert the high-impedance signals of piezoelectric sensors to low-impedance signals, which can transmit across long cable lengths without loss of signal quality. [2]

2 Metra Mess- und Frequenztechnik in Radebeul e.K. (n.d.). IEPE Standard. Retrieved from https:// mmf.de/iepe_standard.htm

The versatility of a dynamic DAQ system comes into play by providing a built-in constant current source, typically 2 to 20 mA (4 mA is the most commonly used value). Types of IEPE sensors include acoustic, acceleration, force, pressure, and vibration. A DAQ system can also directly measure noncompliant IEPE sensors, such as a thermocouple, thermistor or RTD temperature sensors, voltage, current, resistance, and capacitance. For more information about the measurement capabilities of Keysight's DAQ systems, visit http://www.keysight.com/find/DAQ.

Monitor dynamic signals in time and frequency domain

One of the most important measurements when capturing dynamic signals from accelerometers or vibration sensors is the resonance frequency signature of the measurements. Typically, the resonance frequency signature tells a lot about the behavior or characteristics of a physical structure or material when a nonstationary event occurs.

A dynamic DAQ system can capture a nonstationary event, as shown in Figure 4. You can monitor the time domain and the frequency domain of the dynamic signal simultaneously. Some DAQ systems have built-in fast Fourier transform (FFT) or, in this case, use a PC software application that runs FFT to display the dynamic signals in both the time and frequency domain.

Figure 4. Monitoring time domain signal (above) and frequency domain signal (below)

Types of Applications

Dynamic data acquisition applications are numerous across broad industries. Here are some fundamental applications.

1. AC / DC (alternating current / direct current) power analysis

A common component in electrical products is a power converter. It may be an AC-to-DC converter that can receive input power directly from an external AC source via a wall connector or a DC-to-DC converter that changes a higher voltage to a lower voltage (buck converter) or a lower voltage to a higher voltage (boost converter). When testing a DC-to-DC converter, typical parameters of interest include input and output DC voltage and current, AC ripple voltage, temperature rise, and power efficiency.

Figure 5 shows an example of measuring the power efficiency of a DC-to-DC converter. Instruments used for this purpose include a DC power supply, a DAQ with a four-channel simultaneous sampling digitizer, and an electronic load.

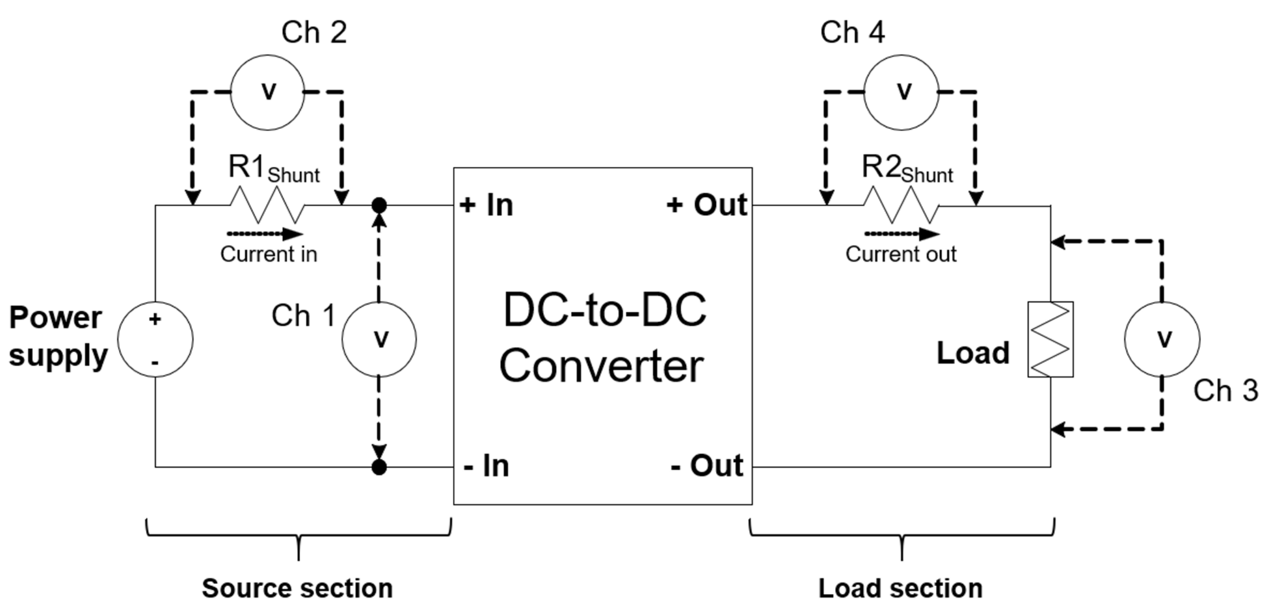

Figure 5. Measuring source power and load power of a DC-to-DC converter

In Figure 5, R1 and R2 are current shunts. For power measurements, a current shunt measures the current. A 0.005 Ω resistor is used so that the voltage drop at high current levels does not appreciably affect the input or output voltage. The DC voltage (Ch 2) is measured across the R1 current shunt, and Ohm's law is then applied to calculate the source current. Multiply the source current by the measured input voltage (Ch 1) to calculate the source power. You can calculate the load power in the same way. Figure 6 shows how to configure the four-channel digitizer to measure the source and load power. Taking a ratio of the output power over the input power gives you the power efficiency of the DC-to-DC converter.

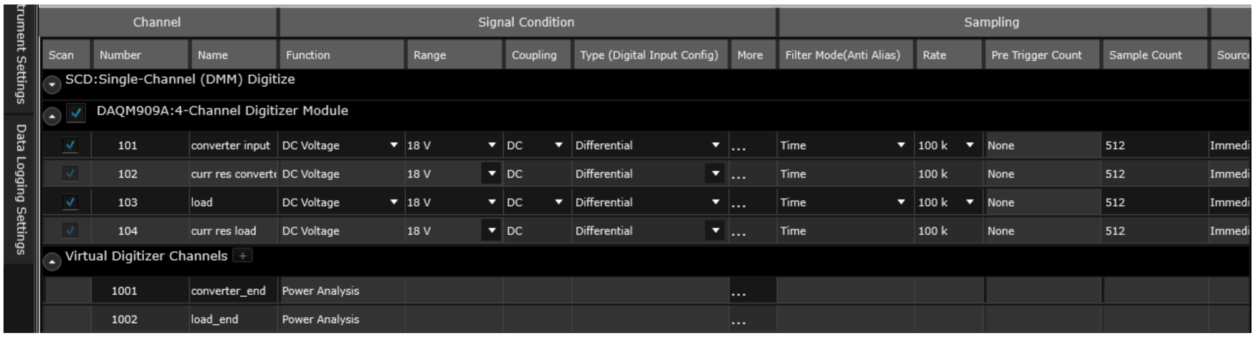

Figure 6. Configuring the four-channel digitizer to measure source and load power

A dynamic DAQ system with at least a four-channel simultaneous sampling digitizer allows you to monitor the source and load power of a DC-to-DC converter. Potential abrupt changes in the source power or load will affect the DC-to-DC converter. In this setup, you will be able to see the dynamic changes simultaneously.

Figure 7 shows an example of a PC application remotely connecting to a dynamic DAQ system measuring and displaying simultaneously the source and load power of a DC-to-DC converter.

Figure 7. Simultaneous display of source and load power of a DC-to-DC converter

2. Electromechanical vibration analysis

Electromechanical vibration analysis is a fundamentally important subject in aerospace, transportation (air, sea, or land), and manufacturing. A dynamic DAQ system can capture multiple channels of dynamic data, then store and display them in the time and frequency domains. Vibrations have a frequency resonance signature or amplitude envelope profile that determines the normal operating conditions of a piece of machinery or a mechanical body structure in motion. Deviations from normal operating conditions may show an abnormal resonance spike at a certain frequency, perhaps indicating a worn-out ball bearing, a mechanical misalignment, or an unbalanced rotary system.

Figure 8 shows how easy it is to set up a piezoelectric sensor to measure the vibration of a cantilever. You can use an accelerometer sensor to measure the acceleration of the cantilever movement.

Figure 8. A dynamic DAQ system capturing a cantilever vibration from a piezoelectric sensor

During setup of the dynamic DAQ system, you can configure an event trigger via external TTL or an internal voltage threshold output of the sensor to initiate the capture of the dynamic signal. The instrument has great flexibility to set measurement settings such as root mean square value, duty cycle, positive width, negative width, rise time, and fall time, useful for quick analysis.

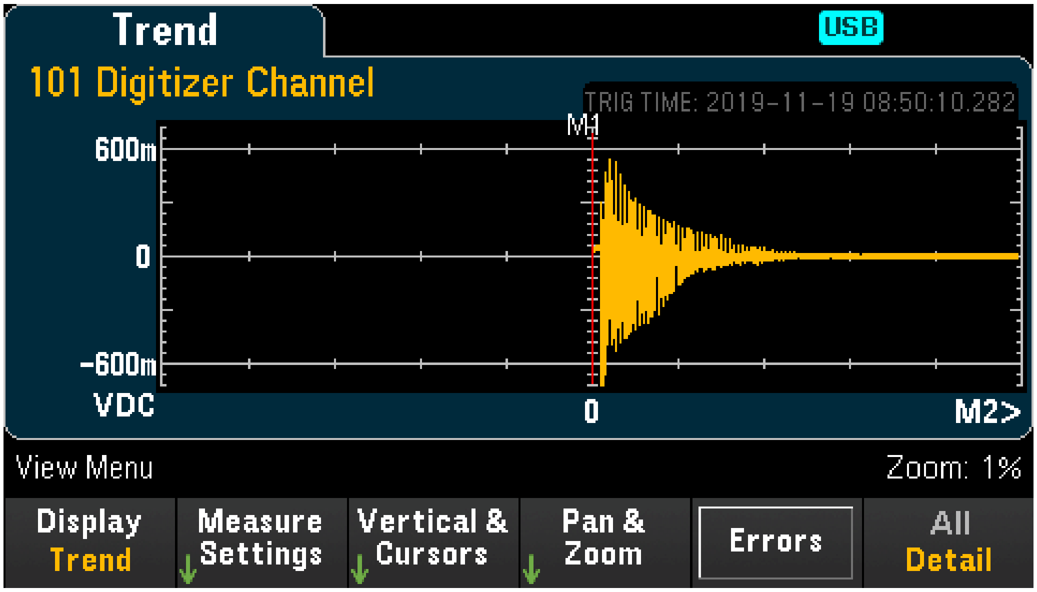

Figure 9. A digitized dynamic signal displayed on a dynamic DAQ system

3. Audio and acoustic analysis

Acoustic analysis uses an audio microphone to capture sound waves of machinery or an engine in operation, then analyzes the dynamic data to diagnose whether a mechanical failure is going to happen.

Acoustic analysis is common in industries that use a lot of heavy machinery. A single instance of unplanned downtime can cost millions of dollars. Acoustic analysis is similar to vibration analysis but with a different focus. Instead of finding the cause of an equipment failure by measuring vibrations at the frequency bandwidth of interest, acoustic analysis measures and monitors focus on contact sound such as ball bearings to determine the health of the equipment and potential proactive lubrication measures. [3]

3 Gribble, J. (2006, January). Acoustic Analysis for the Rest of Us. *Machinery Lubrication.*

Many types of sound frequency microphones can be interfaced with a dynamic DAQ system. Using the correct microphone transducer will allow you to capture high-quality dynamic acoustic signals. For example, air pressure or velocity microphones are suitable transducers for picking up sound waves traveling through the air. Contact pickups are transducers that pick-up sound waves from a dense physical medium such as wood or metal.

In most situations, sound waves converted into electrical signals require some signal conditioning such as preamplification and filtering before you can digitize and store in a dynamic DAQ system. Some DAQ systems have built-in signal conditioners, which makes it easier to configure and quickly start your measurements.

4. Hybrid analysis

In some situations, you do not need to capture dynamic data — for example, temperature, humidity, or strain measurement. You may want to scan a hybrid of static and dynamic data over time. Some DAQ systems allow you to do this to optimize your data acquisition storage and analysis time.

For example, when testing a DC-to-DC converter, you may want to log the ambient temperature, the product temperature, DC voltage and current, dynamic AC ripple data, and power efficiency, all with synchronized time stamps.

In some situations, you may need to perform multiple types of dynamic data analysis. For example, you may want to analyze nonstationary vibration and acoustic (vibroacoustic) data from vehicles (land, sea, and air) and other sources such as industrial machinery and general environmental noise sources. There are good sources of information for nonstationary vibroacoustic data analysis. [4] Some modern DAQ systems give you the flexibility to perform static and dynamic analysis together.

4 Himelblau, H., Wise, J. H., Piersol, A. G., & Grundvig, M. R. (2006). *Handbook for Dynamic Data Acquisition and Analysis: Design, Test, and Evaluation Division Reference Document 012.2*. Institute of Environmental Sciences and Technology.

Features of a Modern DAQ for Dynamic Data Acquisition

A modern dynamic DAQ system offers a high signal sampling rate, time domain analysis, frequency domain analysis, and virtual digitizer channel configuration.

1. High sampling rate

A modern DAQ system requires a fast sampling digitizer to capture dynamic signals. The signal from the sensors or transducers generally outputs voltage signals. The digitizer's sampling rate depends on your application. For example, you would typically use a frequency range of 0 to 100 Hz to measure low-frequency shock, vibration, or strain from vehicle transient events; 10 Hz to 2 kHz for high-frequency vibration and strain; 10 Hz to 10 kHz for high-frequency aeroacoustics; and 100 Hz to 1 MHz for pyroshock measurements. Pyroshock analysis is a measurement of a dynamic structure exposed to an explosion or impact. Transducers for pyroshock analysis are typically accelerometers, strain gauge, electro-optical displacement sensors, and laser Doppler vibrometers.

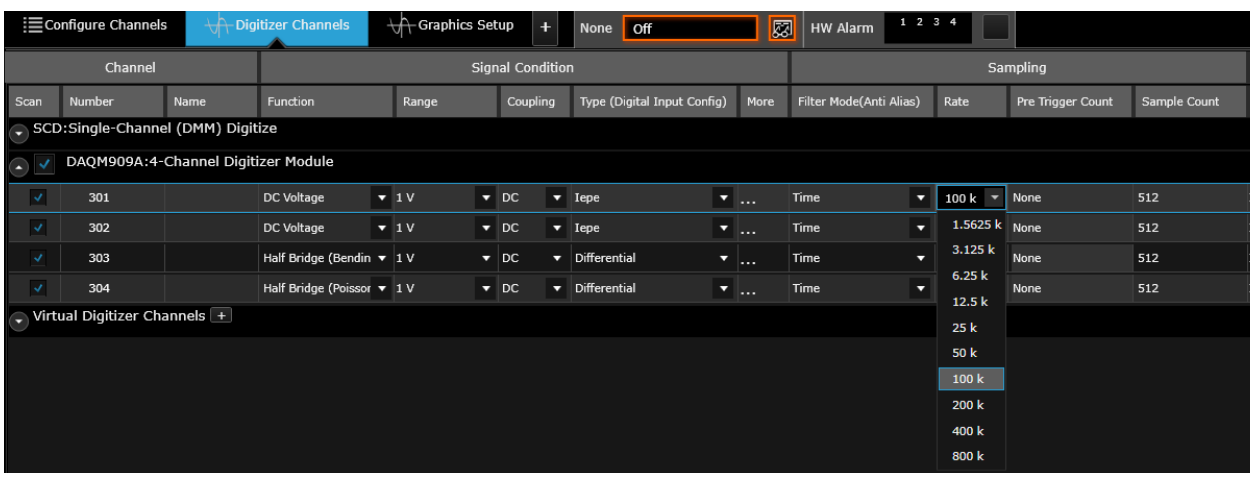

Figure 10. The sampling rate configuration of a digitizer channel for a dynamic DAQ system

2. Time domain analysis

A time domain analysis for a dynamic DAQ system is similar to an oscilloscope. A dynamic DAQ system may not have the high bandwidth of an oscilloscope, but it has signal conditioners that accept many types of sensors and can performing long periods of data logging. Modern DAQ systems now come with PC DAQ application software that controls the DAQ systems and displays all dynamic data in a time domain chart. Figure 11 shows an example of how this PC DAQ application software displays data in a time domain chart. It has quick buttons to measure minimum or maximum amplitude, magnitude, rise or fall time, duty cycle, period, phase, negative or positive width, and a host of statistical measurements.

Figure 11. PC DAQ application software that helps display a time domain chart and derives a host of statistical measurements

3. Frequency domain analysis

When analyzing dynamic signals for vibrations, acoustics, or noise, you need to analyze the dynamic data in the frequency domain. The output of the dynamic data in the frequency domain provides a telltale signature profile of nonstationary machinery operation, unwanted AC power harmonic distortions, or sizing up the type of environmental noise. Some dynamic DAQ systems can quickly help derive total harmonic distortion (THD), total harmonic distortion with noise (THD+N), or signal-to-noise and distortion (SINAD) ratio measurement with the click of a button. Figure 12 shows a PC DAQ application software's ability to complement a dynamic DAQ system instrument to produce a frequency domain chart and all the THD, THD+N, and SINAD measurements.

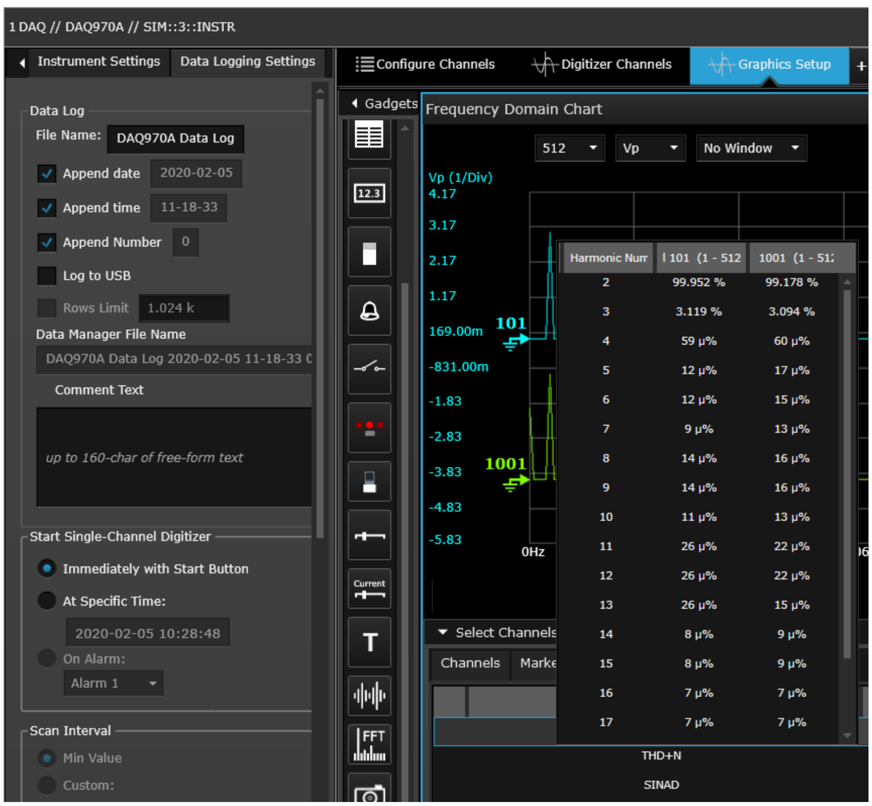

Figure 12. PC DAQ application software that helps display a frequency domain chart and derives THD, TND+N, and SINAD measurements

4. Computed channel or virtual digitizer channel

A dynamic DAQ system can have many channels for measurements. You can also configure a computed channel or a virtual digitizer channel. Figure 13 shows a PC DAQ application software interface that allows you to configure a computed channel using mathematical operations such as multiply, divide, add, and subtract between two real measurement channels. You can even perform a math operation between a real measurement channel with a constant value. This provides much-needed flexibility to display the final measurement units, which you would otherwise have to calculate offline.

You can export these measurements to file formats that MATLAB, Excel, and Word can read for further post-analysis and report-generation work.

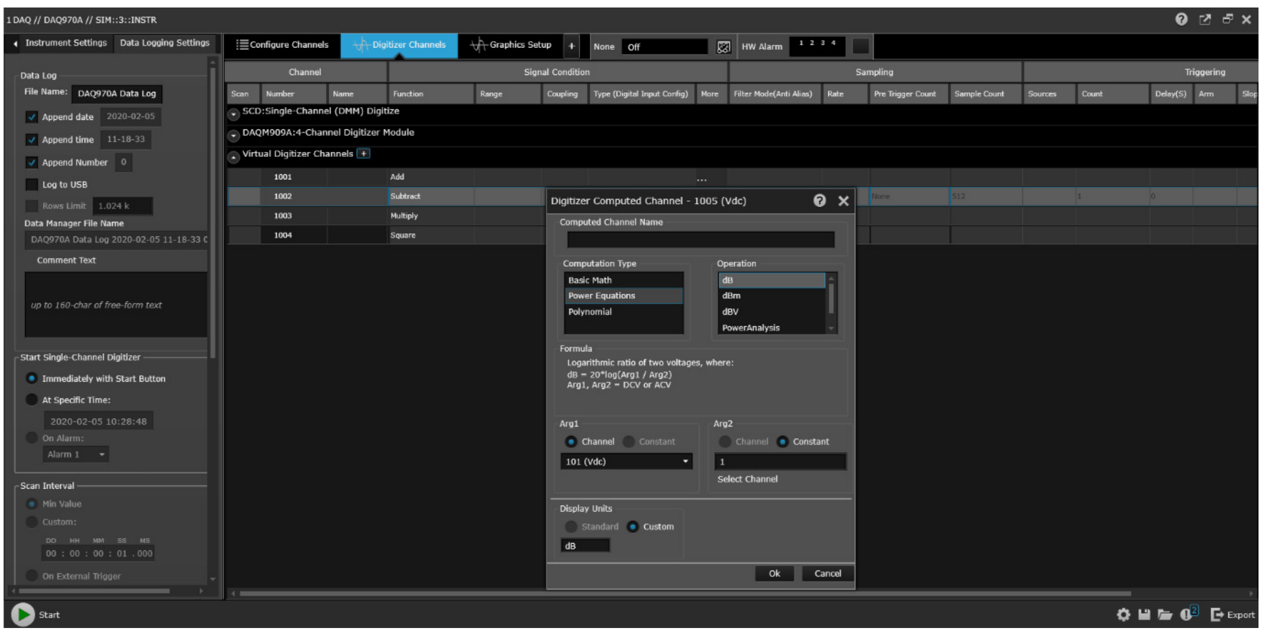

Figure 13. Computed channel configuration setup on a PC DAQ application software

Conclusion

Dynamic data acquisition is not new in the field of measurement science. However, it is becoming increasingly important because products have become more complex in terms of design, integration, and test characterization. Static data acquisition alone cannot catch the dynamic changes of impact shock stresses of a structure, vibration of a motor, or changes in environmental noise. Dynamic data acquisition ensures accuracy and reduces the errors and variability often associated with the acquisition and analysis of dynamic data.

Keysight high-performance DAQ970A / DAQ973A data acquisition systems, in combination with the DAQM909A four-channel simultaneous sampling digitizer module, offer best-in-class features to meet the increasing demand for dynamic data acquisition of end products.

For more information on Keysight's DAQ systems, please visit http://www.keysight.com/find/DAQ.

For more information on Keysight's DAQ PC software application, please visit http://www.keysight.com/find/BenchVue.