1

Getting Started with Order Analysis

Order analysis is a technique for analyzing noise and vibration signals in rotating or reciprocating machinery such as engines, compressors, turbines, and pumps. These machines have a variety of parts, each of which contributes unique noise and vibration patterns to those of the whole machine. With order analysis, you can identify and isolate these patterns to analyze the performance and quality of each machine part individually. The information you gather with order analysis often is difficult to acquire with other analysis methods.

Traditional noise and vibration analysis methods such as FFT analysis cannot detect mechanical characteristics that change with speed. Order analysis, on the other hand, allows you to identify data at various orders, or harmonics of the rotational speed. The first order refers to the speed at which the machine rotates. Each order thereafter is a corresponding multiple of the rotational speed. The second order is twice the rotational speed, the third order is three times the rotational speed, and so on. Using order analysis, you therefore can analyze signal variations due to changes in speed.

Order analysis is useful in two types of applications: machine condition monitoring (MCM) and noise, vibration, and harshness (NVH) testing. MCM applications typically analyze vibration response data to identify defective parts and ensure continuous performance. NVH applications typically evaluate sound and vibration data to verify the quality of a system and identify parts that produce unwanted noise or vibration.

You can use the LabVIEW Order Analysis Toolkit to develop both MCM and NVH applications. This document focuses on using the Order Analysis Toolkit for NVH applications. Refer to the LabVIEW Order Analysis Toolkit User Manual for more information about order analysis theory and applications.

Developing NVH Applications with the LabVIEW Order Analysis Toolkit

NVH applications involve the correction of unwanted noise, vibration, or harshness. For example, commercial airplane engineers might use NVH analysis to reduce cabin noise. With NVH analysis, they can isolate and identify the source of the unwanted noise, such as the aircraft engines. They then can redesign that rotating part and verify the improvement, again using NVH analysis.

Unlike MCM applications, which you can use to identify defective machine parts, NVH applications generally analyze the noise and vibration of machine parts that function properly. However, you can use the same analysis tools for both MCM and NVH applications.

The Order Analysis Toolkit provides VIs and plots with which you can develop a complete NVH application, from the logging of online data to data analysis and presentation. This toolkit also provides examples to illustrate how you can use those VIs and plots in the applications you develop.

Performing Order Analysis with Example VIs

In this document, you perform order analysis with VIs that the Order Analysis Toolkit provides. The Order Analysis Toolkit also provides examples to illustrate both NVH and MCM applications. You can access all examples in the Order Analysis Toolkit by selecting **Help»Find Examples** to display the NI Example Finder and then navigating to the **Toolkits and Modules»Order Analysis** book. Due to the complexity of the Order Analysis VIs, National Instruments recommends that you use the Order Analysis Toolkit examples as a starting point for all order analysis applications that you create.

2

Performing Order Analysis

In this section, you use the Order Analysis Capabilities VI to perform offline order analysis on example data that the LabVIEW Order Analysis Toolkit provides. The example data represents the speed and amplitude of a computer fan during a run-up test, in which the machine speed increases steadily for a certain period of time. The Order Analysis Capabilities VI illustrates the common analysis methods you can use to acquire information about the orders in the run-up data.

Description of the Unit Under Test

An effective order analysis application requires a thorough knowledge of the unit under test (UUT). The more information you have about the UUT, the more useful the analysis you perform can be in understanding the behavior of the system.

The example data used in this application represents a 15-second run-up test of a computer fan with four coils and seven blades. Run-up and coast-down tests are useful for identifying orders that generate significant amplitude only as you approach certain speeds or frequencies.

Analyzing the Example Data

The Order Analysis Capabilities VI utilizes a number of the plots that the Order Analysis Toolkit provides to analyze noise and vibration data. Each plot displays the same information from a different perspective. You can use these plots to analyze the example data and gain a fuller understanding of the UUT.

Loading the Example Data

You can use the Order Analysis Capabilities VI to analyze previously recorded data. The Order Analysis Toolkit also provides example data that you can analyze with this VI.

Complete the following steps to load the fan run-up data to use in the Order Analysis Capabilities VI.

1. From the attached `Getting Started with OAT.llb`, open the Order Analysis Capabilities VI.
2. Click the **Browse** button next to the **Data Path** text box and navigate to `\\labview\examples\Order Analysis\Example Data\PC Fan runup.dat`.
3. Click the **Open** button. The filename appears in the **Data Path** text box.
4. Click the **Run** button to run the Order Analysis Capabilities VI.

You now can use the Order Analysis Capabilities VI to analyze the example data using a variety of plots.

Analyzing the Vibration Signal and Speed Profile Plots

Vibration signal plots illustrate how an acquired noise or vibration signal changes over time. Speed profiles illustrate how rotational speed changes over time. You can use these two plots in parallel to observe how raw noise or vibration changes with speed.

The **Waveform and Speed** tab of the Order Analysis Capabilities VI displays both vibration signal and speed profile plots. From the **Vibration Signal** plot, you can see that the vibration amplitude of the computer fan generally increases over 15 seconds. The **Speed Profile** plot shows that the rotational speed of the fan increases steadily from approximately 1000 to 4000 RPM over 15 seconds.

Analyzing the Vibration Level

A vibration level plot shows how the vibration level of a UUT changes with time or speed. The vibration level is a quantitative measurement of the vibration signal.

Click the **Vibration Level** tab to observe the **Vibration Level Plot** of the computer fan run-up data. By default, this plot displays the vibration level against the rotational speed of the fan. From this plot, you can see that the vibration level increases as rotation speed increases. This trend is especially strong above 3200 RPM.

Change the **X axis selection** to **Time** to observe how the vibration level changes with time. The shape of the curve is similar to the plot of the vibration amplitude against rotational speed.

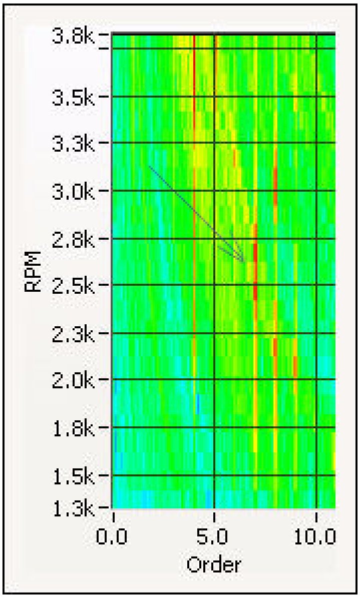
On the **Vibration Level** tab, you also can change the vibration level type, block size, and time or speed segment. The **Vibration level type** specifies the type of level measurement you want to use to calculate the vibration level. The **Block size** specifies the block size of the signal this VI uses to compute the vibration level. The **Time/speed segment [s or rpm]** cluster specifies the segment of time or speed for which you want to calculate the vibration level and at which intervals, or step size, to perform the calculation.

The **Vibration Level Plot** provides summary information about the signal behavior. You can use other order analysis plots to learn more about specific orders.

Analyzing the Color Map

A color map is a three-dimensional display of a noise or vibration spectrum as a function of time or speed. The spectrum can be a frequency or order spectrum. A spectral map provides an overview of the frequency or order content of a signal related to the time or speed.

Click the **Color Map** tab of the Order Analysis Capabilities VI to display a color map of the computer fan run-up data. By default, this plot displays rotational speed against order. Red portions of the color map indicate areas of high intensity. Notice that several red, vertical lines appear on this color map. These vertical lines correspond to strong vibrations from different orders in the data. For example, you can see that the seventh order is strongest between 2400 and 2800 RPM.

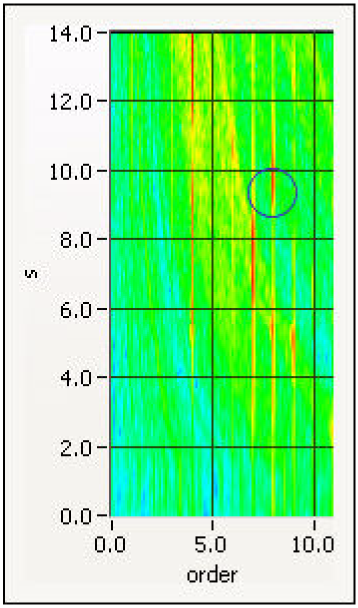


Change **Plot type** to **Time-Order**. This plot type displays how the vibration intensity at different orders changes with time. With this plot, you can see that the seventh order is strongest between approximately 6 and 8 seconds.

Now change **Plot type** to **Frequency-Time** to observe a plot of the signal frequency against time. From this plot, you can see that the strongest vibrations occur at frequencies between 150 and 400 Hz. This range probably includes several resonant frequencies from the UUT.

The **Max order to analyze** control on the **Color Map** tab specifies the maximum order for which you want an accurate measurement of intensity. The **Color Map** displays more orders than you select because it uses the additional orders for internal calculations. The **Speed/time segment [rpm or s]** cluster specifies the segment of time or speed for which you want to calculate the vibration intensity and at which intervals, or step size, to perform the calculation.

With the **Color Map**, you can identify orders that correspond to loud noises or strong vibrations that you observe. For example, suppose the machine under test generates loud noises between 9 and 10 seconds. From the **Time-Order** plot, you can quickly see that the noises most likely come from the eighth order.

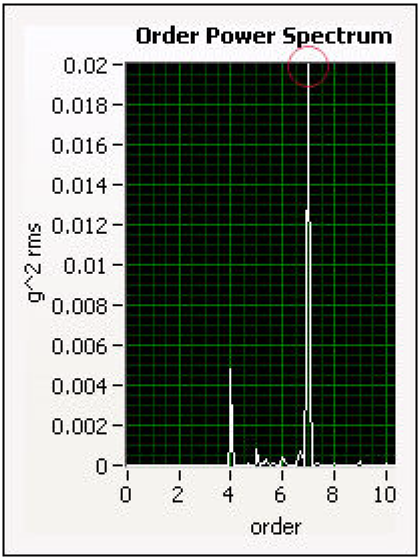


The **Color Map** therefore provides an overview of how the intensity of the signal relates to time, speed, frequency, and order.

Analyzing the Order Power Spectrum

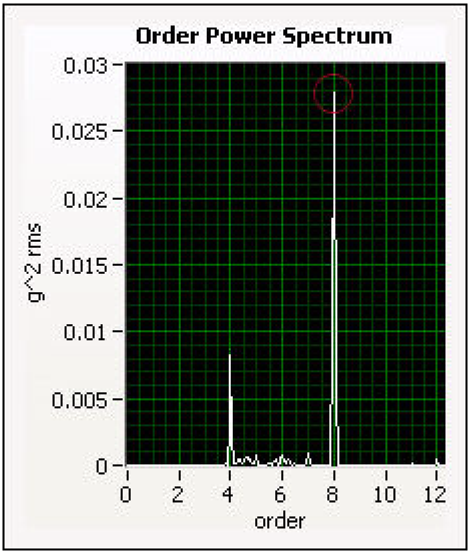
An order power spectrum provides a quantitative description of the rotation-related components during a certain time period. This plot helps you find and compare significant orders.

Click the **Order Power Spectrum** tab of the Order Analysis Capabilities VI to observe the **Order Power Spectrum** for the computer fan run-up data. By default, this plot displays the order amplitudes between 0 and 2 seconds. However, suppose you want to observe the order amplitude for the seventh order. You can see from the **Time-Order** plot on the **Color Map** tab that the seventh order is strongest between 6 and 8 seconds. Therefore, on the **Order Power Spectrum** tab, change **Start [s]** to `6.00` and keep **Duration [s]** at `2.00` to display the **Order Power Spectrum** between 6 and 8 seconds. From this plot, you can see that the seventh order is indeed strongest in this time range, with an amplitude of .02 g^2 rms.



The fourth order also is significantly strong during this time period. The seventh and fourth orders correspond to the 7 blades of the fan and 4 coils of the electric motor, respectively.

Similarly, from the **Time-Order** plot on the **Color Map** tab, you can see that the seventh order loses intensity at around 9 seconds and the eight order gains intensity around this same time period. Therefore, on the **Order Power Spectrum** tab, change **Start [s]** to `9.00` and change **Duration [s]** to `1.00`. You see that the eighth order now has a much greater amplitude than the seventh order does.



Again, the fourth order also is significantly strong during this time period. The eighth order and other order multiples of four correspond to the four coils of the electric motor of the fan.

On the **Order Power Spectrum** tab, you also can specify the **Window type** and **Block size** to use to calculate the order power spectrum. In addition, you can use the **dB On** input to specify whether to display the results in decibels.

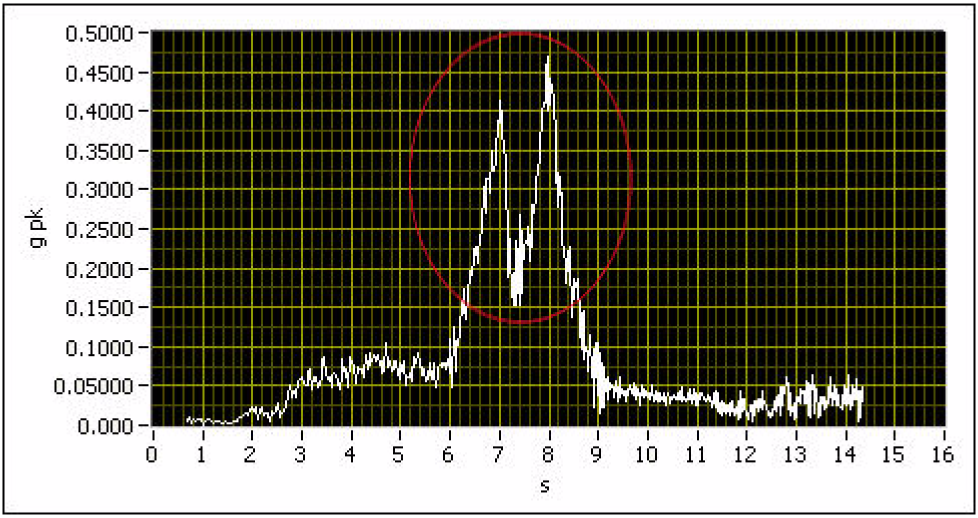
The **Order Power Spectrum** therefore provides detailed information about the strength of each order at a specific period in time.

Analyzing the Magnitude Plot

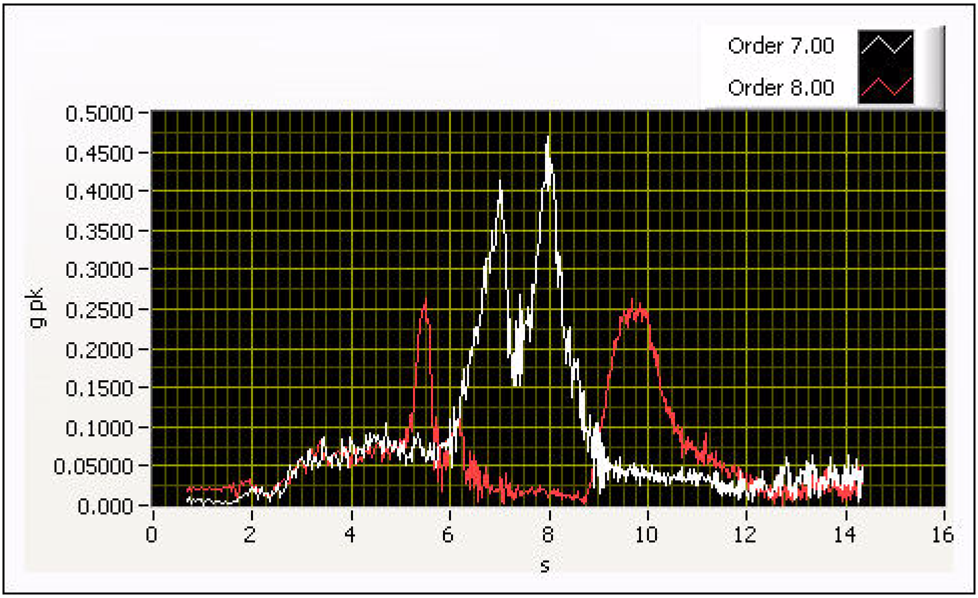
Recall that the color map showed the seventh order with a strong amplitude between 6 and 8 seconds. You can use a magnitude plot to observe this order in greater detail.

Click the **Order Tracking** tab of the Order Analysis Capabilities VI to view the **Magnitude** plot for the computer fan run-up data. By default, this plot shows the magnitude, in peak measurements, of the first order over time. Change the first element of the **Orders to compute** array to `7.00`. The **Magnitude** plot now shows the magnitude of the seventh order over time. You can see that this order does indeed have greater intensity between

6 and 8 seconds, with a dip between 7 and 8 seconds. This dip is difficult to observe with the color map alone.



You also can use the **Order Tracking** tab to compare different orders. For example, change the second element of the **Orders to compute** array to `8.00`. The **Magnitude** plot now displays the seventh and eighth orders together.



As you observed with both the color map and the order power spectrum, between 8 and 10 seconds, the intensity of the eighth order increases as the intensity of the seventh order decreases. The **Magnitude** plot provides a detailed view of exactly how the two orders change in magnitude over time.

You can change the **X axis selection** for the **Magnitude** plot to display the order magnitude against time, number of revolutions, or RPM. You also can use the **Magnitude view** input to specify the type of quantitative measurement you want to use to calculate the magnitude.

Whereas an order power spectrum shows the values of all orders at a specific period in time, the **Magnitude** plot provides detailed information about the particular orders that you specify.

Click the **Stop** button to stop the Order Analysis Capabilities VI.

Extracting Waveform Orders

One useful analysis method for NVH applications that the Order Analysis Capabilities VI does not illustrate is waveform order extraction. With waveform order extraction, you can isolate and extract specific orders from the noise or vibration signal. You then can perform further analysis on these significant orders.

For example, suppose you want to minimize the amount of noise inside a car. You acquire a noise signal and, through order analysis, identify an order that produces a particularly loud noise. With knowledge of the UUT, you determine that this order is associated with the timing belt. You cannot remove the timing belt from the UUT, but you can minimize the noise it produces. To determine how best to minimize the noise, you can extract the associated order in the noise signal, attenuate that order by a certain decibel level, and reconstruct the noise signal with the attenuated order. You then can play back the resulting signal to evaluate the harshness of the sound. In this way, you can reduce the harshness of the signal and remove undesirable noise and vibrations.

You can use the OAT Extract Order Waveforms VI or the OAT Extract Most Significant Order Waveforms VI to isolate orders of a signal that you specify or that are the strongest. The Extract Most Significant Orders (Offline) example VI illustrates how to use the OAT Extract Most Significant Order Waveforms VI to isolate the strongest order waveforms in a simulated signal or recorded data. Select **Help»Find Examples** to display the NI Example Finder and then navigate to **Toolkits and Modules»Order Analysis»Functions»Extract Most Significant Orders (Offline) .vi** to open this example VI.

Summary

You can use the Order Analysis Capabilities VI to perform most common types of order analysis. This VI displays the data using the following plots:

- Vibration signal plot
- Speed profile plot
- Vibration level plot
- Color map
- Order power spectrum
- Magnitude plot

You also can use VIs that the Order Analysis Toolkit provides to extract specific orders from the signal to perform a more detailed analysis. You can use this information and knowledge of the UUT to verify the noise and vibration quality of the system.